Threats to *Acropora* spp. in the Caribbean

Richard B. Aronson,
Dauphin Island Sea Lab, 101 Bienville Boulevard, Dauphin Island, AL 36528

William F. Precht,
PBS&J, 2001 Northwest 107th Avenue, Miami, FL 33172

Mass mortalities of *Acropora palmata* and *Ac. cervicornis* on Caribbean reefs over the last three decades have caused drastic declines in coral cover throughout the region. Although hurricanes and cold-water events (in Florida and the Bahamas) have killed acroporids on some reefs, white-band disease has been the single most significant source of mortality on a regional level. Paleontological work in Belize suggests that the *Acropora* kill is without precedent in at least the last 3-4 Kyr. Analysis of 36 reef cores extracted from a 375-km^2 area of the central shelf lagoon showed that *Ac. cervicornis* dominated continuously for at least the last 3,000 yr. The lettuce coral *Agaricia tenuifolia* occasionally grew in small patches until the late 1980s. Within a decade, *Ac. cervicornis* was virtually eliminated by white-band disease. *Ag. tenuifolia* recruited to and grew on the dead coral branches and was the dominant coral by the mid-1990s. The scale of species turnover increased from tens of square meters or less to hundreds of square kilometers or more. Paleontological data from the Dominican Republic, St. Croix and the Bahamas support the hypothesis that the current situation is unprecedented on a millennial scale.

In fore reef environments, the establishment of damselfish territories and other localized mortality were responsible for variability at the smallest spatial and temporal scales (square meters, months to years) within populations of acroporids. Hurricane damage introduced variability at larger spatial and temporal scales (kilometers to tens of kilometers, years to 1-2 decades). The spatial scale of mortality of *Acropora* spp. has increased to a regional scale, virtually eliminating variation at a range of smaller spatial and temporal scales.

Current threats to remnant populations of *Acropora* include hurricanes, disease, corallivory, hyper- and hypothermic stress, sea-level rise and pollution. These threats generally act in combination rather than individually. The life history strategies of *Ac. palmata* and *Ac. cervicornis* are not conducive to rapid recovery from regional mass mortality. At present, agariciids and poritids are the most common corals colonizing the disturbed surfaces of reefs formerly occupied by acroporids.

Focal *Acropora* spp. Assessment in the Florida Keys

Margaret W. Miller

NOAA/NMFS, Southeast Science Center, 75 Virginia Beach Dr, Miami, FL 33149

This presentation will summarize two recent assessments of *Acropora* spp. status. The first involves population surveys of elkhorn coral, *Acropora palmata*, and its predator, the corallivorous snail *Coralliophila abbreviata*, in the Key Largo area. Surveys were conducted annually in May from 1998 to 2001 at six sites in the FKNMS; three no-take zones and three reference areas. At each survey, size and condition of each sampled coral colony was estimated as well as the number and size of its resident snails. A drastic decline in *A. palmata* populations was observed between May 1998 and May 1999, coinciding with a severe bleaching event and Hurricane Georges during summer/fall of 1998. All colonies in three patches (out of 10, ~200 colonies) sampled in 1998 suffered complete mortality by May 1999. Sampling at two sites in October 1998, after Hurricane Georges, confirmed that average sizes of standing colonies and of loose fragments had decreased while the abundance of fragments had increased. The total amount of live *A. palmata* (as measured by total # of colonies or by total "live area index") extant at three sites where all colonies were sampled declined drastically from 1998 to 1999 and has shown only marginal recovery from 1999 to 2001. The incidence of white band disease (WBD) in these *A. palmata* patches has been consistently low throughout the study, below 6% for any given site survey with zero incidence observed in many site surveys. The average incidence of WBD observed in 2001 was 2% of colonies (n=6 sites). The average density of corallivorous snails on *A. palmata* (#/*A. palmata* colony surveyed, n=6 sites) more than doubled from 1998-2000 but declined slightly between 2000 and 2001 (overall mean ~0.8 for 2001). Sites with low-density *A. palmata* stands (LD sites) had consistently more snails colony^{-1} (0.8-2.5) than sites with thickets (0.4-1.0). Meanwhile, the average size of snails on *A.palmata* declined between 1998 - 1999 and has rebounded somewhat by 2001. Published measurements of average snail consumption rate are ~1-2 (cm^{2}live *A.palmata* tissue)snail^{-1}d^{-1} with individual measurements ranging up to 6.5 (cm^{2}live *A.palmata* tissue)snail^{-1}d^{-1}.

The second assessment evaluated change in total *Acropora* spp. cover at Looe Key (lower Keys) over a longer time frame. In 2000 the occurrence and approximate size of all *A. palmata* and *A. cervicornis* colonies was recorded on scaled base maps of the spur and groove structure at Looe Key and compared to archival maps made with the same scaled base maps in 1983. Total areal loss for the mapped area was estimated at 93% for *A.palmata* and 98% for *A. cervicornis*. It is likely that considerable *Acropora* spp. loss had occurred prior to 1983, and is thus not included in these estimates.

Lastly, recent attempts at larval culture of *A.palmata* for restoration will be described.

Status of Acropora Corals in the Florida Keys:
Habitat Utilization, Coverage, Colony Density, and Juvenile Recruitment

Mark Chiappone, Steven Miller and Diane Swanson
Center for Marine Science and NOAA's National Undersea Research Center,
University of North Carolina at Wilmington, 515 Caribbean Drive, Key Largo, FL 33037, USA
Tel: 305 451 0233, Fax: 305 453 9719, Email: chiapponem@uncwil.edu

As part of an ongoing, large-scale assessment and monitoring program in the Florida Keys, this study collected coverage and colony density data for *Acropora* corals in the region, including Dry Tortugas National Park and Tortugas Bank. The results presented are considered preliminary because our initial sampling program was not optimized for surveying the coverage and density of *Acropora* corals. During 1999-2001, a total of 260 sites were sampled in the region, including 204 sites from southwest of Key West to northern Key Largo (Figure 1) and 56 sites in Dry Tortugas National Park, the Tortugas Bank, Riley's Hump, and south of the Marquesas Keys (Figure 2). As part of our larger program, sampling was stratified with respect to habitat type, geographic region, and protection from fishing to ascertain spatial variations in mean percent coverage, species presence-absence, density of juveniles, and the density, size, and disease prevalence of colonies > 4 cm maximum diameter. In randomly selected sampling locations, 10m or 25 m transects were used for linear point-intercept estimates of cover, and 1 m swaths were surveyed for the presence and density of *Acropora* colonies. During 2001, larger transects (25 m x 2 m) were also used to obtain density estimates of both species. Eight habitat types were surveyed from nearshore to the deeper fore reef (15 m) and included mid-channel and offshore patch reefs, back reef rubble, high-relief spur and groove, low-relief hard-bottom, and low-relief spur and groove. Sites were further classified by geographic region into the lower, middle, and upper Keys.

Mean percent coverage for both *Acropora* species, as determined from surveys of 100 points for each of four transects per site, was low (Table 1 and Figure 3). In the Florida Keys, mean coverage by *A. cervicornis* was 0.049% among the eight habitat types and did not vary significantly. Mean cover was greatest on high-relief spur and groove reefs (0.049%) and offshore patch reefs (0.045%). Mean coverage by *A. palmata* was even lower throughout the Florida Keys than its congener, even on many high-relief spur and groove reefs where it was formerly abundant. Among the eight habitat types surveyed, *A. palmata* was only recorded in high-relief spur and groove. Mean coverage in this habitat type was 0.158% and ranged from 0.158% in the lower Keys, 0.300% in the middle Keys, to 0.338% in the upper Keys. The density of *Acropora* colonies was quantified in 25 m x 0.4 m or 10 m x 0.4 m transects. For *A. cervicornis*, mean colony densities among the eight habitat types were no greater than 0.052 colonies/m^2 and there were no significant differences detected in mean colony density among habitat types (Table 3). Offshore and mid-channel patch reefs had the greatest mean densities (0.047-0.052 colonies/m^2). Within strip transect surveys, colonies of *A. palmata* were only found in the high-relief spur and groove habitat. The mean density estimate for this habitat type was 0.036 colonies/m^2, ranging among regions from 0.010/m^2 in the middle Keys, 0.015/m^2 in the lower Keys, and 0.073/m^2 in the upper Keys. Patches of numerous colonies were evident at Sand Key, Eastern Dry Rocks, Molasses Reef, Sand Island, and Elbow Reef, most of which are within Sanctuary no-fishing zones.

The prevalence of disease or disease-like conditions indicated relatively low prevalence of for both *Acropora* species, although few colonies were assessed during 1999-2001 (Table 4). Of the 31 *A. cervicornis* encountered, only one colony exhibited signs of possible recent disease. Three of the 18 colonies of *A. palmata* assessed exhibited either white band disease or signs of recent disease, evidenced by dead white skeleton. Not surprisingly, few juveniles for either *Acropora* species were encountered from the 260 Florida Keys sites. Reconnaissance surveys in several locations, however, did reveal some smaller colonies presumably derived from sexual recruitment, supported by the lack of nearby colonies.

Because density estimates using 25 m x 0.4 m or 10 m x 0.4 m transects were so low for both *Acropora* species, the 2001 surveys also included larger and additional transects to assess densities (Tables 5-6). For the Florida Keys shallow fore reef, both spur and groove and hardbottom were surveyed from Key West to northern Key Largo at 2 m to 8 m depth. Densities were extremely patchy (Table 5 and Figure 4) and despite the relatively large sample area, only 43 colonies of *A. cervicornis* and 302 colonies of *A. palmata* were recorded. Maximum densities for particular reefs were 2.25 colonies/m^2 for *A. cervicornis* and 12.13 colonies/m^2 for *A. palmata* (Figure 4). In low-relief hard-bottom areas, 50 *A. cervicornis* and 18 *A. palmata* colonies were encountered and were even more patchily distributed.

Table 1. Mean percent coverage of *Acropora cervicornis* and *A. palmata* by habitat type and regional sector in the Florida Keys, 1999-2001 (Miller et al., NURC/UNCW).

Habitat/regional strata (no. sites)	*Acropora cervicornis*		*Acropora palmata*	
	Mean % cover	SE	Mean % cover	SE
Mid-channel patch reef (16)	0.016	0.022	---	---
Lower Keys (6)	---	---	---	---
Middle Keys (8)	---	---	---	---
Upper Keys (2)	0.125	0.145	---	---
Offshore patch reef (22)	0.045	0.052	---	---
Lower Keys (12)	0.083	0.128	---	---
Middle Keys (1)	---	---	---	---
Upper Keys (9)	---	---	---	---
Back reef rubble (7)	---	---	---	---
Lower Keys (7)	---	---	---	---
Inner line reef tract (4)	---	---	---	---
Upper Keys (4)	---	---	---	---
High-relief spur and groove (46)	0.049	0.089	0.158	0.174
Lower Keys (24)	0.073	0.158		
Middle Keys (5)	0.100	0.407	0.300	0.733
Upper Keys (17)	---	---	0.338	0.400
Low-relief hard-bottom (62)	0.012	0.014	---	---
Lower Keys (13)	0.058	0.060	---	---
Middle Keys (28)	---	---	---	---
Upper Keys (21)	---	---	---	---
Patchy hard-bottom in sand (8)	---	---	---	---
Lower Keys (1)	---	---	---	---
Middle Keys (6)	---	---	---	---
Upper Keys (1)	---	---	---	---
Low-relief spur and groove (39)	0.006	0.011	---	---
Lower Keys (25)	0.010	0.019	---	---
Middle Keys (11)	---	---	---	---
Upper Keys (3)	---	---	---	---

Table 2. Survey effort and number of *Acropora cervicornis* and *A. palmata* colonies sampled for colony density in the Florida Keys, 1999-2001 (Miller et al., NURC/UNCW).

Habitat/regional strata	No. sites surveyed	Survey area (m²)	*A. cervicornis*	*A. palmata*
Mid-channel patch reef				
Lower Keys	6	34.8	---	---
Middle Keys	8	32.6	---	---
Upper Keys	2	12.4	6	---
Subtotal	16	79.8	6	---
Offshore patch reef				
Lower Keys	12	107.6	13	---
Middle Keys	1	5.6	---	---
Upper Keys	9	50.6	---	---
Subtotal	22	163.8	13	---
Back reef rubble				
Lower Keys	7	140.0	---	---
Inner line reef tract				
Upper Keys	4	61.0	---	---
High-relief spur and groove				
Lower Keys	24	283.7	3	2
Middle Keys	5	63.6	2	1
Upper Keys	17	194.7	1	15
Subtotal	46	542.0	6	18
Low-relief hard-bottom				
Lower Keys	13	230.4	4	---
Middle Keys	28	506.0	---	---
Upper Keys	21	403.6	---	---
Subtotal	62	1140.0	4	---
Patchy hard-bottom in sand				
Lower Keys	1	20.0	---	---
Middle Keys	6	110.0	---	---
Upper Keys	1	20.0	---	---
Subtotal	8	150.0	---	---
Low-relief spur and groove				
Lower Keys	25	558.7	2	---
Middle Keys	11	220.0	---	---
Upper Keys	3	60.0	---	---
Subtotal	39	838.7	2	---
Total	204	3115.3	31	18

Table 3. Mean density (no. colonies/m^2) of *Acropora* colonies (> 4 cm max. diameter) by habitat type and regional sector in the Florida Keys, 1999-2001 (Miller et al., NURC/UNCW).

Habitat/regional strata (no. sites)	*Acropora cervicornis*		*Acropora palmata*	
	Mean colonies/m^2	SE	Mean colonies/m^2	SE
Mid-channel patch reef (16)	0.047	0.047	---	---
Lower Keys (6)	---	---	---	---
Middle Keys (8)	---	---	---	---
Upper Keys (2)	0.375	0.375	---	---
Offshore patch reef (22)	0.052	0.031	---	---
Lower Keys (12)	0.094	0.055	---	---
Middle Keys (1)	---	---	---	---
Upper Keys (9)	---	---	---	---
Back reef rubble (7)	---	---	---	---
Lower Keys (7)	---	---	---	---
Inner line reef tract (4)	---	---	---	---
Upper Keys (4)	---	---	---	---
High-relief spur and groove (46)	0.009	0.004	0.036	0.025
Lower Keys (24)	0.010	0.006	0.015	0.015
Middle Keys (5)	0.020	0.020	0.010	0.010
Upper Keys (17)	0.005	0.005	0.073	0.064
Low-relief hard-bottom (62)	0.004	0.002	---	---
Lower Keys (13)	0.018	0.010	---	---
Middle Keys (28)	---	---	---	---
Upper Keys (21)	---	---	---	---
Patchy hard-bottom in sand (8)	---	---	---	---
Lower Keys (1)	---	---	---	---
Middle Keys (6)	---	---	---	---
Upper Keys (1)	---	---	---	---
Low-relief spur and groove (39)	0.003	0.002	---	---
Lower Keys (25)	0.004	0.003	---	---
Middle Keys (11)	---	---	---	---
Upper Keys (3)	---	---	---	---

Table 4. Proportional prevalence of *Acropora* corals affected by diseases in the Florida Keys, 1999-2001. N = total number of colonies sampled (Miller et al., NURC/UNCW).

Species	Condition	No. colonies affected	Prevalence (proportion)
A. cervicornis	Dead white skeleton	1	0.0323
	Non-diseased	30	0.9677
	Total	31	1.0000
A. palmata	Dead white skeleton	1	0.0556
	White band disease	2	0.1111
	Non-diseased	15	0.8333
	Total	18	1.0000

Table 5. Mean (± 1 SE) *Acropora* densities (no. colonies/100 m^2) in Florida Keys fore reef habitats (2-8 m depth) during 2001, using 25 m x 2 m transects. Sites are arranged from southwest to northeast and those marked with an asterisk are Sanctuary no-fishing zones.

Habitat type/region/site	Area (m^2)	*Acropora cervicornis* No. colonies/100 m^2	*Acropora palmata* No. colonies/100 m^2
Western Dry Rocks	800	---	0.63 ± 0.50
Sand Key*	800	---	11.13 ± 6.62
Eastern Dry Rocks*	800	---	1.63 ± 1.36
Marker 32	400	---	---
Western Sambo Reef*	800	2.25 ± 0.80	3.50 ± 3.50
Middle Sambo Reef	800	0.25 ± 0.25	---
Eastern Sambo Reef*	800	---	0.13 ± 0.13
No Name Reef	400	0.13 ± 0.13	---
Pelican Shoal	400	---	---
East of Pelican Shoal	400	---	---
American Shoal	400	1.25 ± 0.48	---
Lower Keys Subtotal	6,800	0.54 ± 0.20	1.84 ± 0.94
Sombrero Key*	800	0.13 ± 0.13	1.50 ± 1.00
East Delta Shoal	400	1.25 ± 1.25	
Middle Keys Subtotal	1,200	0.50 ± 0.42	1.00 ± 0.69
Pickles Reef	1,200	---	0.08 ± 0.08
Molasses Reef*	800	---	0.25 ± 0.16
Sand Island	400	---	11.75 ± 8.25
Elbow Reef*	800	---	12.13 ± 9.08
South of S. Carysfort	800	---	---
Carysfort/S. Carysfort Reef	1,600	0.25 ± 0.25	1.13 ± 0.46
Upper Keys Subtotal	5,600	0.07 ± 0.07	2.88 ± 1.48
Spur and groove total	**13,600**	**0.35 ± 0.11**	**2.19 ± 1.77**
Marker 26	400	1.50 ± 1.50	---
Maryland Shoal	1,600	1.94 ± 0.52	---
East of Looe Key	400	---	---
West of Big Pine Shoal	400	---	---
Lower Keys Subtotal	2,800	1.32 ± 0.39	---
Delta Shoal	800	0.88 ± 0.64	---
Crocker Reef	800	---	---
Davis Reef*	800	---	0.13 ± 0.13
Little Conch Reef	800	1.38 ± 0.60	---
Southwest of Conch Reef	400	---	---
Conch Reef*	800	---	---
Northwest of Conch Reef	800	---	2.13 ± 2.13
Middle Keys Subtotal	5,200	0.25 ± 0.12	0.35 ± 0.33
Little Pickles Reef	400	---	---
Southwest of Molasses Reef	400	---	---
Northeast of French Reef	1,200	---	---
Dixie Shoal	800	---	---
Dixie Shoal	800	---	---
Upper Keys Subtotal	3,600	---	---
Hard-bottom total	**11,600**	**0.43 ± 0.12**	**0.16 ± 0.15**

Table 6. Mean (± 1 SE) density (no. colonies/100 m^2) of *A. cervicornis* in Florida Keys mid-channel and offshore patch reef habitats during 2001, using 10 m x 2 m transects. Sites are arranged from southwest to northeast and those marked with an asterisk are Sanctuary no-fishing zones.

Habitat type/site	Region	Sample area (m^2)	*Acropora cervicornis* No. colonies/100 m^2
Mid-channel patch reef			
South of Sunshine Key	Middle Keys	160	1.25 ± 1.25
East Washerwoman	Middle Keys	160	---
South of Vaca Key	Middle Keys	160	---
East of Marker 49	Middle Keys	160	0.63 ± 0.63
Turtle Shoal	Middle Keys	160	---
East Turtle Shoal	Middle Keys	160	---
Cheeca Rocks*	Middle Keys	320	---
South of Molasses Channel	Upper Keys	320	9.06 ± 5.24
Habitat subtotal		**1,600**	**2.00 ± 1.15**
Offshore patch reef			
Northwest of Davis Reef	Middle Keys	160	---
West of Pickles Reef	Upper Keys	160	---
West of Molasses Reef	Upper Keys	320	5.31 ± 2.97
White Banks/Dry Rocks	Upper Keys	320	---
East of Mosquito Bank	Upper Keys	160	---
South of Carysfort Reef	Upper Keys	160	---
West of Carysfort Reef*	Upper Keys	320	---
Habitat subtotal		**1,600**	**1.06 ± 0.67**
All patch reef types		**3,200**	**1.53 ± 0.67**

Figure 1. *Acropora* survey locations throughout the Florida Keys, 1999-2001.
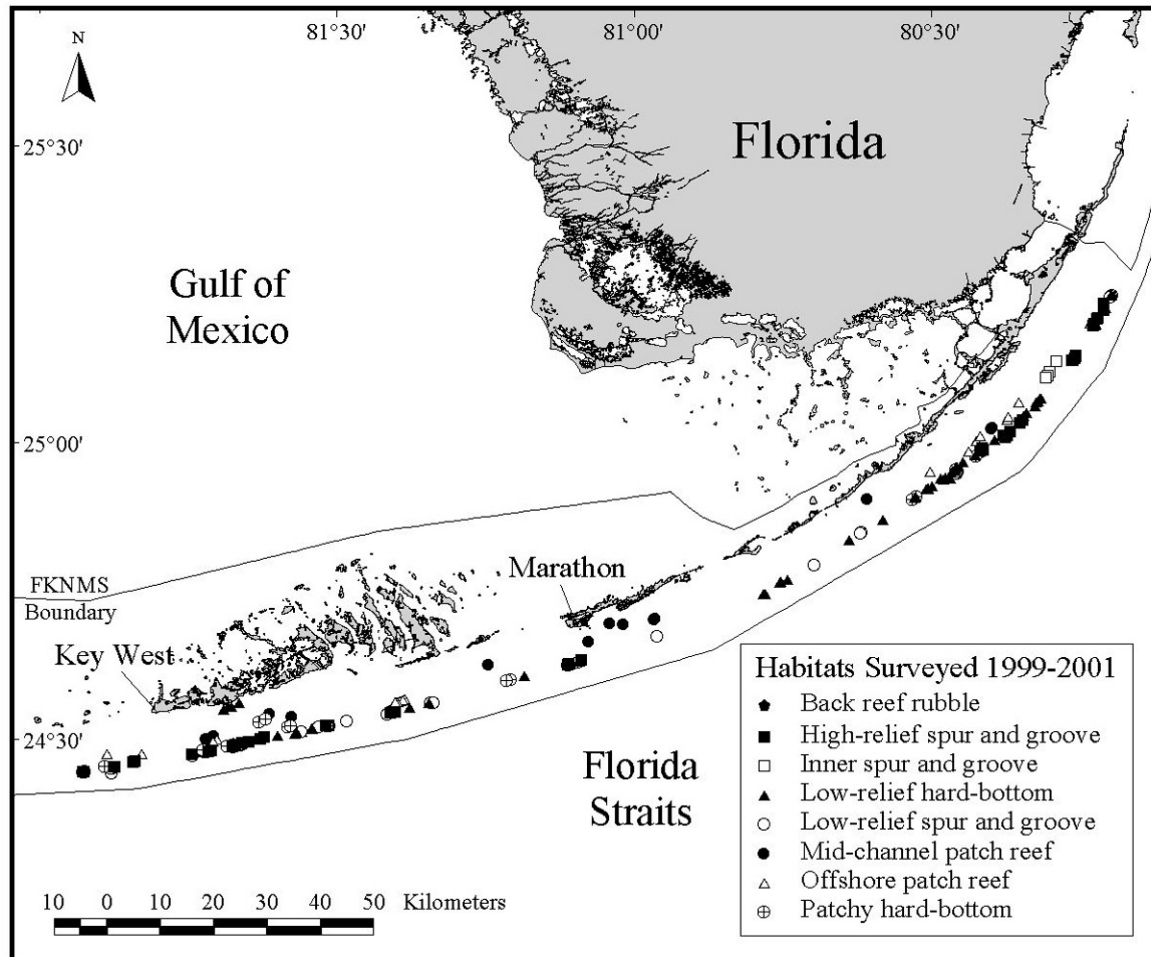
Figure 2. *Acropora* survey locations in the Tortugas, 1999-2000.
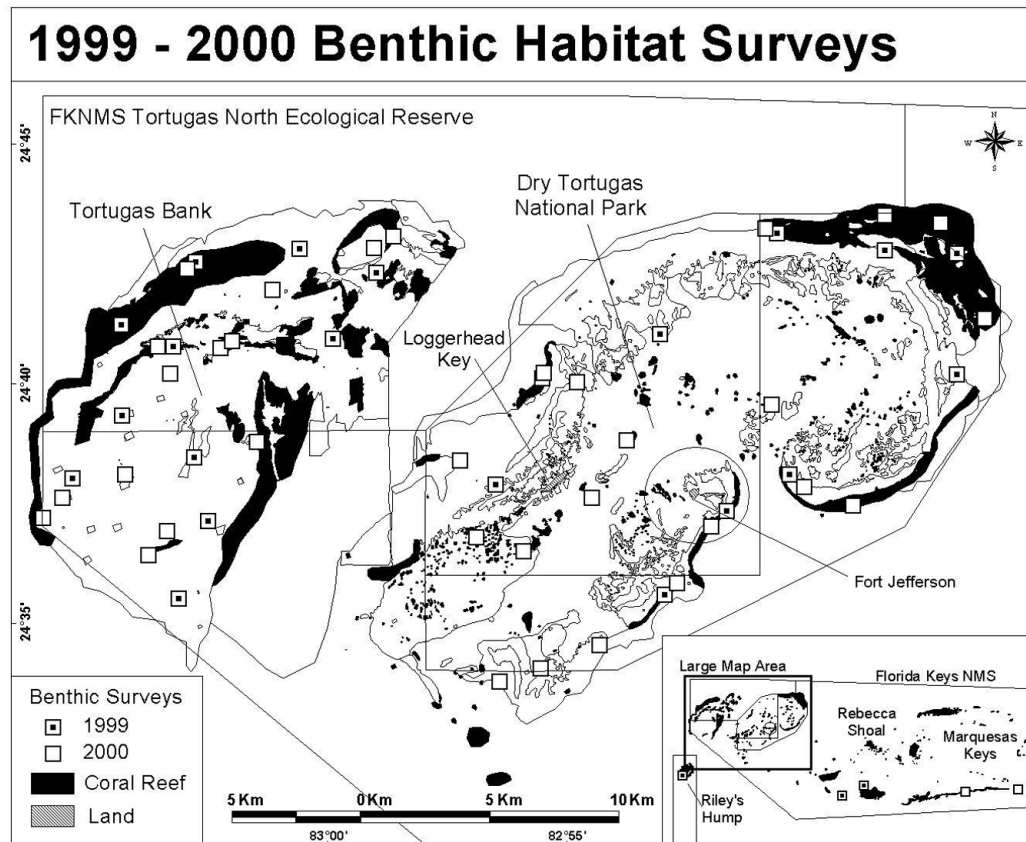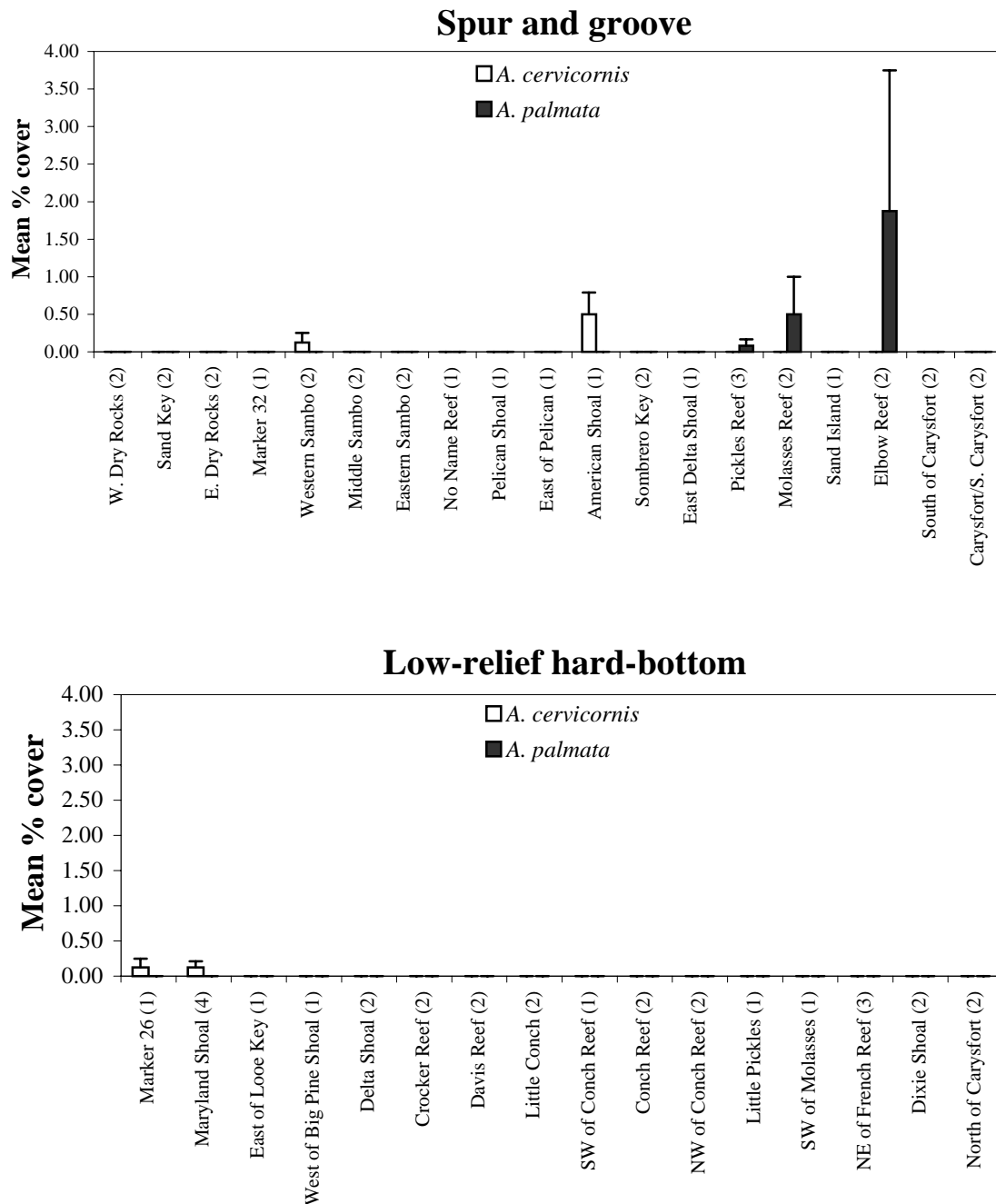
Figure 3. Mean percent cover of *Acropora cervicornis* and *A. palmata* on high-relief spur and groove reefs (top) and low-relief hard-bottom (bottom) on the Florida Keys fore reef during 2001. Sites are arranged from southwest to northeast and error bars represent one standard error. Values in parentheses are the number of sites surveyed for each reef, with 100 points surveyed along each of four 25 m transects per site.

Figure 4. Mean density (no. colonies/100 m^2) of *Acropora cervicornis* and *A. palmata* on high-relief spur and groove reefs (top) and low-relief hard-bottom (bottom) on the Florida Keys fore reef during 2001. Sites are arranged from southwest to northeast and error bars represent one standard error. Values in parentheses are the number of sites surveyed for each reef, with 400 m^2 surveyed for colony numbers per site.
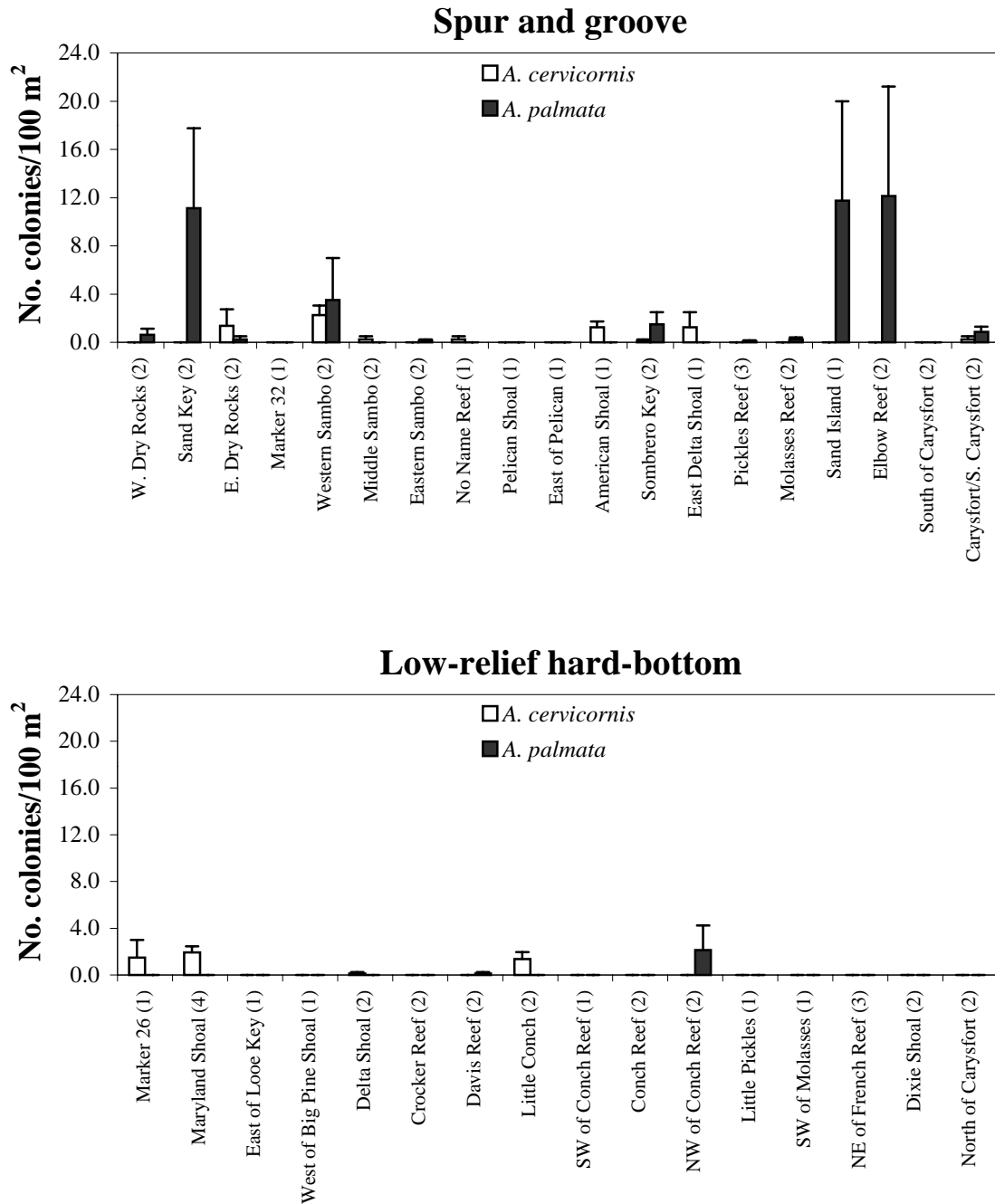
Acropora- A Review of Systematics, Taxonomy, Abundance, Distribution, Status, and Trends: Florida, 1881 - 2000

Walter C. Jaap

Florida Marine Research Institute, Fish and Wildlife Conservation Commission

Systematics

Phylum Cnidaria
    Class Anthozoa Ehrenberg, 1834
        Subclass Zoantharia deBlainville, 1830
            Order Scleractinia Bourne, 1900
                Suborder Astrocoeniina Vaughan and Wells, 1943
                  Family Acroporidae Verrill, 1902
                    Genus *Acropora* Oken, 1815
                        Acropora palmata (Lamarck, 1816)
                        Acropora cervicornis (Lamarck, 1816)
                        Acropora prolifera (Lamarck, 1816)

Genus description:
Acropora: Branched, bushy, plate-like, sometimes encrusting. Axial and radial corallites on branches. Two cycles of septa (=12); porous corallite walls, corallites without columella. The type species is *Acropora muricata* (Linné 1758), missing, type locality unknown.

Geographic distribution: Pacific and Indian Oceans, Red Sea, Persian Gulf, Western Atlantic-Caribbean.

Stratigraphy: Eocene (58×10^6 YBP) to Recent

Veron and Wallace (1984) reported that there were 364 extant species of *Acropora*, 361 in the Indo Pacific and three in the western Atlantic. The three western Atlantic species, *A. palmata, A. cervicornis, and A. prolifera* are commonly referred to as elkhorn, staghorn, and fused staghorn corals.

Acropora palmata
Madrepora palmata Lamarck, 1816
Madrepora muricata forma palmata Brook 1893
Madrepora muricata Duerdan, 1899
Madrepora (Acropora) palmata Mayer, 1914
Acropora palmata (Lamarck) Vaughan, 1915
Acropora palmata (Lamarck) Wells and Lang, 1973
Acropora palmata (Lamarck) Veron 2000

Description: *Acropora palmata* is the largest of all *Acropora* species; colonies are up to four meters from branch tip to branch tip, two meters high, with a base trunk that is up to 40 cm in diameter. The base is firmly attached to the substrate. Branches are flat or less commonly round, tubular radial corallites are of various diameters and length. Brown to yellow-gold color.

Geographic distribution: Known from Dry Tortugas to Broward County in Florida. In the western Atlantic, *A. palmata* is known from the Bahamas, Greater and Lesser Antilles, Venezuela, Aruba, Bonaire, Curacao, Colombia, Panama, Nicaragua, Honduras, Belize, Mexico.

Stratigraphy: Late Pliocene to recent.

Bathymetry and habitat preference: Depth range is <1 to17 m, optimal range 1 to 5 m. The nominal habitat is the seaward face of a reef such as the spur and groove formations and seaward portion of the reef flat. Branch fragments are often found occupying back reef areas following storms; *A. palmata* may form extensive barrier reef structures such as in Belize, Greater Corn Island, and Roatan.

Reproduction and growth: *Acropora. palmata* is a hermaphroditic broadcast spawning species. The prime time for releasing eggs and sperm is in August and September. We documented that eggs, ova, and sperm were present in tissues (histological analysis) during June through August, 1978-1980. In 1977 and 1981, we did not see evidence of reproduction. Growth rate (branch extension) is 4 to 11 cm per year in Florida. A colony that was 2 meters in height would be 18 to 50 years old. The 4 cm rate is based on Vaughan's early studies in Tortugas and probably under estimates growth. *Acropora palmata* can rapidly spatially monopolize large areas by fragment propagation. Fragments cleaved from the colony may grow into new individuals (Highsmith et al., 1980; Bak and Criens, 1981; Tunnicliffe, 1981; Highsmith, 1982; Rogers et al., 1982; Tunnicliffe, 1984).

Acropora cervicornis

Madrepora cervicornis Lamarck, 1816
Madrepora cervicornis Pourtalés, 1871
Acropora cervicornis (Lamarck) Goreau and Wells, 1967
Acropora cervicornis (Lamarck) Veron, 2000

Description: *Acropora cervicornis*: Arborescent, tubular branches, distinct axial-tubular corallites at branch terminals and radial corallites distributed relatively uniformly on branches. Radial corallites often form bracts rather than tubes. Secondary branches diverge from primary branches at 30 to 90 degree angles. Specimens from deep water tend to have long and slender (about 1.5-cm in diameter) branches and fewer secondary branches. Branches of colonies from shallow water tend be thicker (about four cm in diameter) with a greater number of secondary branches. The color ranges from gold and yellow to brown. Colonies are often not firmly attached to the substrate. Branches may fuse to adjacent branches (anastomosis) forming a pretzel-like maze. Large thickets form a complex structure than may be two to three meters in height and 30 meters long (seen in Dry Tortugas in the early to mid 1970s).

Bathymetry: The species was reported to depths of 50 m off Discovery Bay, Jamaica (Goreau and Wells, 1967), but is more often seen in depths of 3 to 30 m in Florida.

Reproduction and growth: The species is a hermaphroditic, broadcast spawner. The ova, eggs, and sperm were seen during summer of 1978, 1979, and 1981; in 1979, there was active gonad generation from January through June (unpublished data). Propagation from fragments is common (Gilmore and Hall, 1976, Tunnicliffe, 1981). Growth rate for *A. cervicornis* is 4 to 12 cm per year. The species has a more rapid growth during warmer months in Florida (Jaap, 1974).

Acropora prolifera

Madrepora prolifera Lamarck, 1816
Madrepora prolifera (Lamarck) Pourtalés, 1871
Isopora muricata forma *prolifera* Vaughan, 1901
Acropora prolifera (Lamarck) Cairns et al. 1991

This species is the most enigmatic of the three. It is confused with *A. cervicornis* and poorly studied. The distribution includes Dry Tortugas, Yucatan, Belize, Jamaica, Columbia, Panama, and the Netherlands Antilles.

Florida status and trends

Acropora palmata:

Dry Tortugas- 1882 to 1993. Estimated area of coverage went from 109 acres (Agassiz, 1882), to 0.15 acres (Davis, 1982), to 0.35 acres (Jaap and Sargent, 1993).

Elkhorn Reef, Biscayne National Park, 1977 to 1981, *A. palmata* abundance ranged from 8 to 28 colonies (Figure 4) along three 25 m long transects from 1977 to 1981 (Jaap, 1983).
Key Largo- 1981 to 1986. At Elbow Reef, abundance ranged from 66 to 84 colonies within 16 one m^2 quadrats. At French reef, abundance ranged from 42 to 99 colonies within 26 one m^2 quadrats. At Molasses Reef, abundance ranged from 79 to 135 colonies within 25 one m^2 quadrats. The trend these reefs was very stable populations (Figures, 5-8).

Looe Key, 1983. Seventeen *Acropora palmata* colonies occurred in six quadrats on a spur, 2 to 7 m depth.

Coral Reef Monitoring Project, USEPA WQPP, 1996 to 2000, data from 160 video transects from north Key Largo to Smith Shoal. *A. palmata* occurred at five shallow reef sites. Data are processed by point count analyses, we identify benthos and substrate for approximately 600 points at each station, and there are four stations per reef. Percent cover data are computed from the relative number of points that were covering *A. palmata* colonies.

The percent cover contributed by *A. palmata* at upper Keys Reefs ranged from 7.23 percent in 1996 to 0.95 percent in 2000. In the lower Keys reefs, *A. palmata* cover ranged from 7.27 percent in 1996 to 0.85 percent in 2000 (Figures 10, 11).

Acropora cervicornis

In Dry Tortugas, Agassiz (1882) estimated *A. cervicornis* covered 1030 acres; Davis (1982) estimated coverage at 1181 acres. In 1976-77 a hypothermic event occurred, killing 90 to 95 percent of the population of *A. cervicornis* and *A. prolifera* at Dry Tortugas (Walker 1981, Porter et al., 1982). In 1983 there was a loss from a disease that caused significant losses of *A. cervicornis* (Peters et al., 1983).

In a study of several reefs in Biscayne National Park from 1977 to 1981 we saw a decile in abunce at Elkhorn Reef (N= 3 transects) of 32 to 15 colonies (Figure 4).

In a study at Key Largo Reefs from 1981 to 1986 we observed a decline of 175 to 0 colonies at French Reef and 120 to 3 colonies at Molasses Reef (Figures 7, 8).

In the CRMP study we observed declines: in the upper keys, *A. cervicornis* declined from 0.13 percent cover in 1996 to 0.03 percent in 2000, in the middle Keys, *A. cervicornis* declined from 0.26 percent cover in 1996 to 0.00 percent in 2000, and in the lower Keys. *A. cervicornis* declined from 0.11 percent cover in 1996 to 0.02 percent in 2000. In Dry Tortugas, at White Shoal, we saw a relatively stable abundance in *A. cervicornis* (Figures 12-15).

Causes for *Acropora* declines in Florida

Natural disturbances: hurricanes, hypothermia, hyperthermia, winter storms (1992 storm of the century).

Diseases: the white disease seen in *A. palmata* and in *A. cervicornis* can be very serious Gladfelter (1977) and Peters et al. (1983, 1986) report on the impact and causative pathogen.

Predators that feed on *Acropora* include the fire worm *Hermodice carunculata* (Marsden, 1960, Glynn, 1960); the gastropod *Coralliophilla abbreviata* (Brawley and Adey, 1981), the three spot damsel fish (Kaufman, 1977, Potts, 1977). Competitors for lebensraum (space): Fleshy algae (Lighty, 1981)
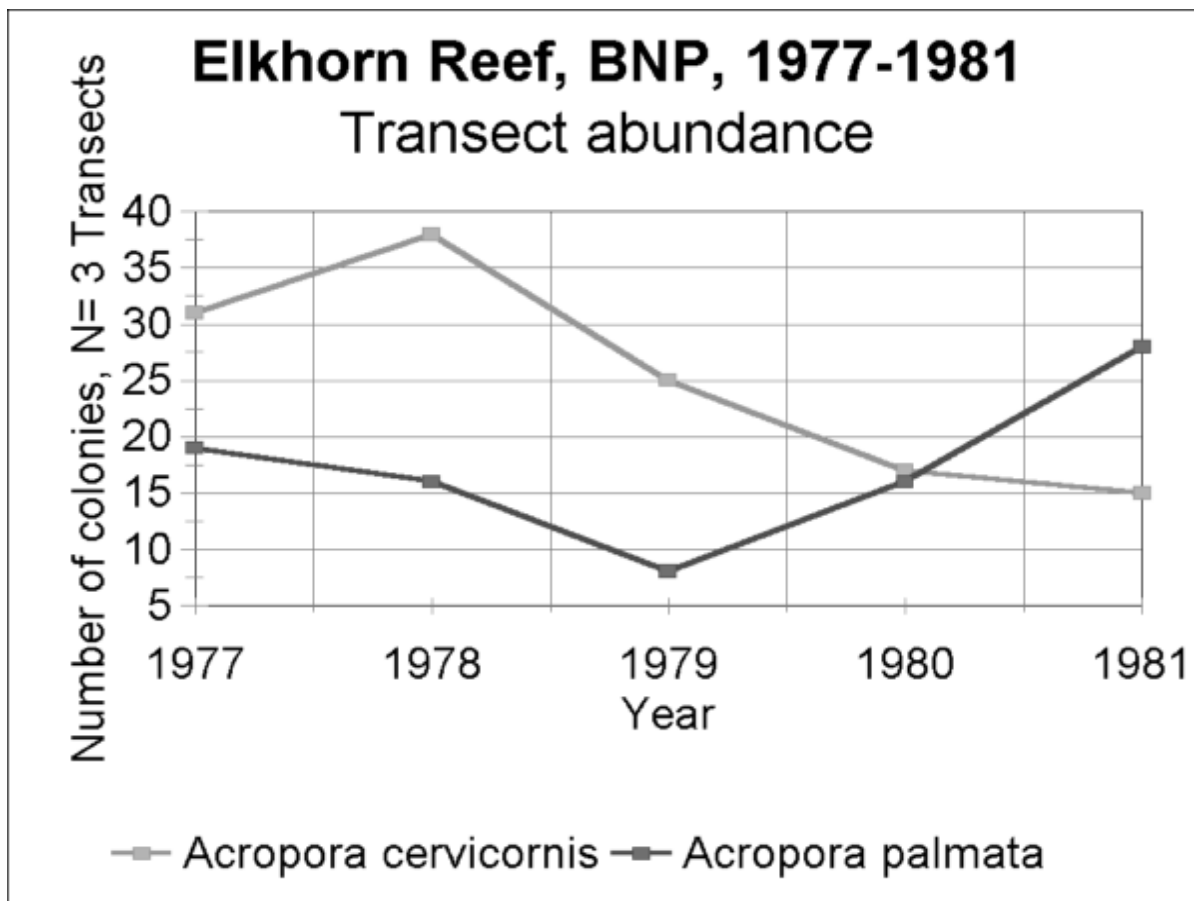
Figure 4. Abundance of *Acropora palmata* and *A. cervicornis* at Elkhorn Reef, Biscayne National Park, three 25 m long continuous line transects parallel to the depth contours (3 to 5 m depth).
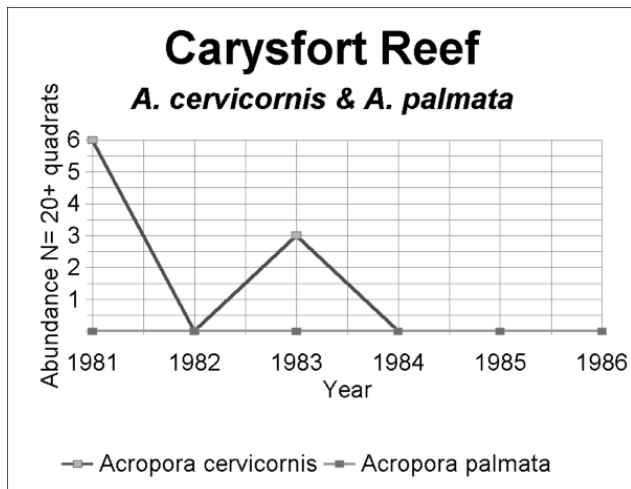
Figure 5. Abundance of *Acropora palmata* and *A. cervicornis*, Carysfort Reef, 1981-1986, based on inventory of 16 1m² quadrats per year.
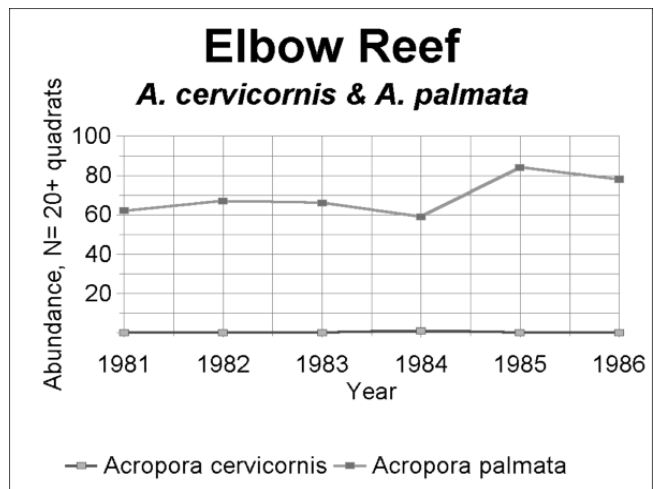

Figure 6. Abundance of *Acropora palmata* and *A. cervicornis*, Elbow Reef, 1981-1986, based on inventory of 26 1m² quadrats per year.
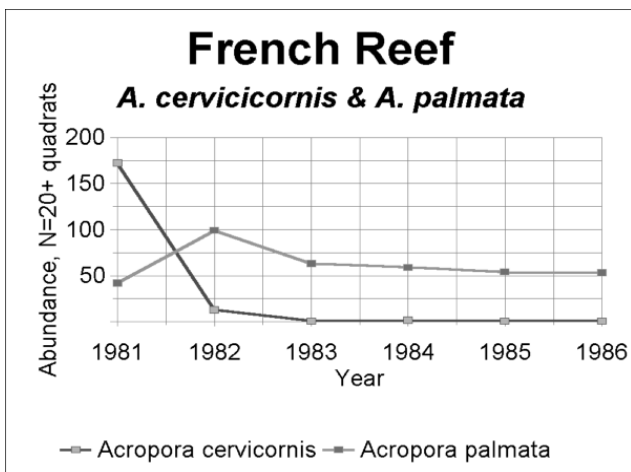

Figure 7. Abundance of *Acropora palmata* and *A. cervicornis*, French Reef, 1981-1986, based on inventory of 27 1m² quadrats per year.
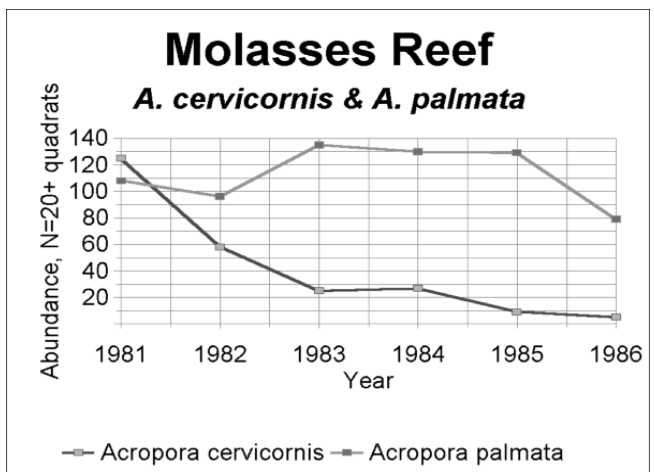

Figure 8. Abundance of *Acropora palmata* and *A. cervicornis*, Molasses Reef, 1981-1986, based on inventory of 25 1m² quadrats per year.

Figure 10. *Acropora palmata* cover at Upper Keys locations, 1996 to 2000, point count analysis of video images.
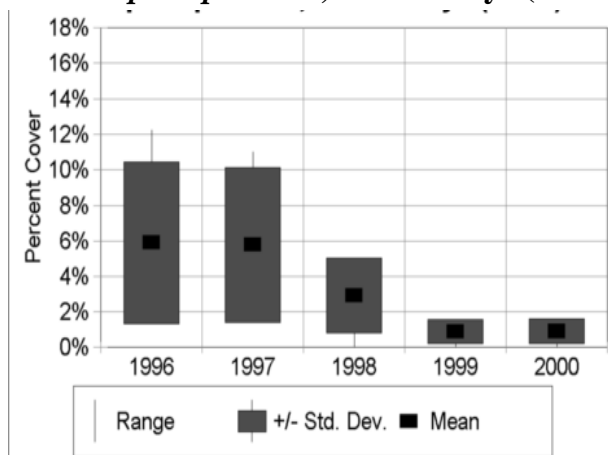
Figure 11. *Acropora palmata* cover at lower Keys locations, 1996 to 2000, point count analysis of video images

Acropora palmata, Upper Keys (n=7)
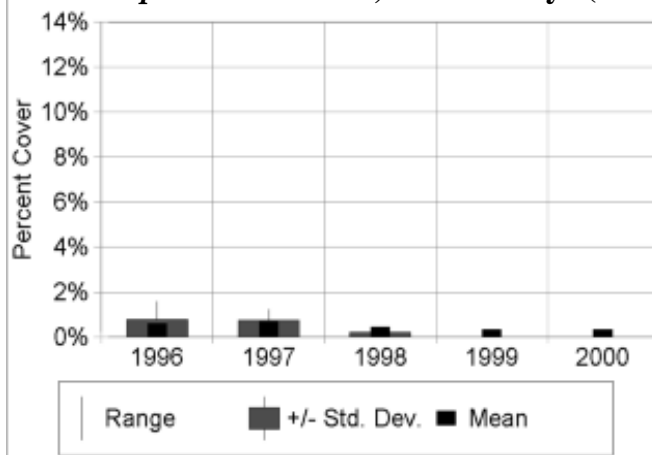

Acropora palmata, Lower Keys (n=12)
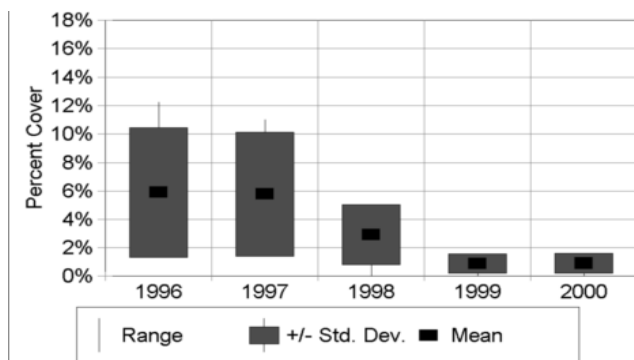
Figures 12-15, Percent cover by *A. cervicornis*, CRMP sites, upper keys, middle keys, lower keys, and Dry Tortugas, point count analyses of video images.
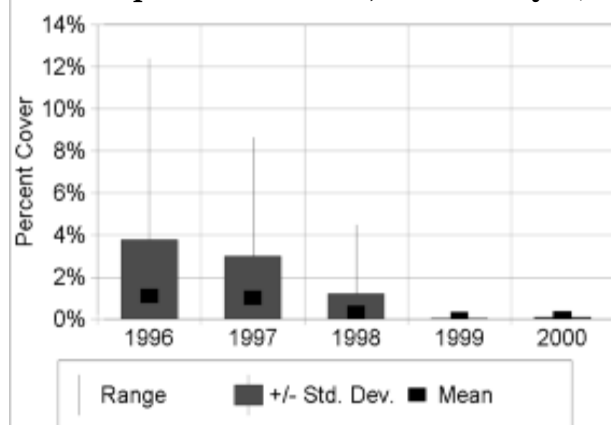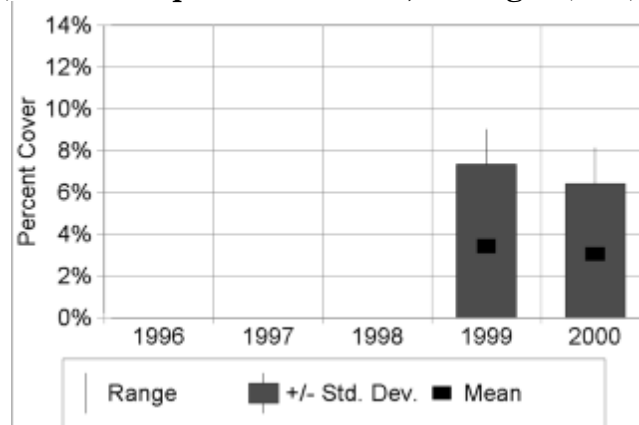
12. *Acropora palmata*, Lower Keys (n=12)

13. *Acropora cervicornis*, Middle Keys (n=9)

14. *Acropora cervicornis*, Lower Keys (n=25)

15. *Acropora cervicornis*, Tortugas (n=7)

141

Distribution, Population Ecology, and Reproductive Biology of *Acropora cervicornis* in Broward County, Florida. USA.

Bernardo Vargas-Ángel and James D. Thomas
National Coral Reef Institute, Nova Southeastern University Oceanographic Center,
8000 N. Ocean Drive, Dania Beach, Florida 33004

During previous research by the National Coral Reef Institute (NCRI) aggregations of staghorn coral (*Acropora cervicornis*) were found distributed along the coastal waters off Fort Lauderdale. These corals appear to flourish beyond known temperature constraints and in the midst of significant anthropogenic stressors. The National Coral Reef Institute has established a basic research program aimed to investigate aspects of the population structure and propagation dynamics of this species off the coast of Broward County. Ongoing studies have located over a dozen sites with conspicuous staghorn coral aggregations. These occur between 600 and 800 m offshore in approximately 4–6 m depth. Patches range between 700 and 7000 m^2, and estimates of mean coral cover range from 5 and 30%, with *A. cervicornis* accounting for 87–97% of all scleractinians. Evidence of predation on *A. cervicornis* at the study sites is noticeable, mainly by the fire worm *Hermodice carunculata* and the gastropod *Coralliophila abbreviata.* Conversely, no incidence of white-band disease or bleaching of *A cervicornis* has been detected to date. Histological examinations have revealed progressive gametogenesis, and mass release of egg-sperm bundles was observed on the night of 6 August 2001, with a high proportion of colonies (~70%) spawning. Additional research interests include the study of disturbance dynamics, namely storm events and sedimentation. In light of the catastrophic demise of *A. cervicornis* throughout the Caribbean, the flourishing population off Fort Lauderdale is perhaps both the largest and northernmost aggregation of *A. cervicornis* in the continental U.S.A., and represent a potential source of propagules to repopulate/ replenish other previously impacted south Florida coral reef habitats.

Status of *Acropora* spp. Populations in
Northern and Eastern Puerto Rican Coral Reefs

Edwin A. Hernández-Delgado

University of Puerto Rico, Dept. Biology, Coral Reef Research Group, P.O. Box 23360, San Juan, P.R. 00931-3360. coral_giac@yahoo.com

Background

Acroporid coral populations have declined significantly in the northern and eastern Puerto Rican coral reefs during the last three decades. Almy and Carrión-Torres (1963), Mckenzie and Benton (1972), Goenaga and Cintrón (1979), and Hernández-Delgado (1992) listed the presence of *Acropora* spp. in different northeastern Puerto Rican reefs, where living colonies are now rarely seen or completely absent. For example, Goenaga and Cintrón (1979) informed large monotypic stands of *A. palmata* on Cayo Largo (Fajardo) and Cayo Batata (Humacao), with 90-100% living cover. These are actually long gone. The situation of the Acroporids in general in critical. Many environmentally-degraded fringing coral reef habitats along the shoreline of Puerto Rico (i.e., Punta Picúa, Punta Miquillo; Río Grande) show large stands of dead *A. palmata* on their growing position, which suggests that mortality might have been the result of disease outbreaks or other biological factor, in possible combination with poor water quality and high sedimentation rates. In addition, there are many coral reefs (i.e., Islote Palominitos, Los Corchos Reef, Cayo Dákity, Playa Larga; Culebra) which show severe physical destruction of the *A. palmata* framework as a result of the hurricane impacts (Goenaga, 1990). Major recent destructive hurricanes included David (August 31, 1979), Hugo (September 18, 1989), Louis (September 6, 1995), Marilyn (September 16, 1995), and Georges (September 21, 1998). It is the combined (cumulative, synergistic) effects of natural and anthropogenic factors which have caused this major decline.

Although there is a major lack of quantitative data regarding the ecological status of Acroporids in general in Puerto Rico, I was able to document the distribution of *A. palmata*, *A. cervicornis*, and *A. prolifera* along 88 northern and eastern Puerto Rican coral reefs in a presence/absence basis. Information was obtained from the available literature (reviewed by Hernández-Delgado, 2000) and from recent unpublished observations. Where possible, data was compared from previous reports and/or personal observations with recent reports or personal observations. Data was geographically sub-divided according to Hernández-Delgado (2000) into four provinces: northern inshore, eastern inshore, eastern offshore close (<6 km), and eastern offshore remote (>6 km). This classification was originally based on a Bray-Curtis ordination analysis for coral species presence/absence data sets to classify coral reefs (Hernández-Delgado, 2000).

Results

The variations in the frequency of observations (presence/absence data) of the three Atlantic *Acropora* species in northern and eastern Puerto Rican coral reefs was summarized in Table 1. Table 2 list all of the surveyed reefs. *Acropora palmata* was a major reef builder in most of the surveyed coral reefs (83-100%). However, at present it only was documented in 32 to 82% of the surveyed reefs as one moves across an anthropogenic environmental stress gradient. During the last three decades, this species has disappeared from 68% of the surveyed reefs from northern Puerto Rico. It has also disappeared from

53% of the eastern inshore reefs and from 32% of the offshore close (< 6 km) reefs. It has only disappeared from 4% of the offshore remote reefs (>6 km).

As for *A. cervicornis*, it was rarely documented from the northern and eastern reefs. In spite of that, it has become absent from 100% of the surveyed sites. It has also disappeared from 43% of the eastern offshore close reefs. No net changes in the frequency of observations was documented from eastern offshore remote reefs. However, it should be mentioned that, absolutely in all of the surveyed reefs from this province, *A. cervicornis* populations have declined significantly due to a combination of factors (discussed below).

As for *A. prolifera*, it was very rare in all of the four geographic provinces. It disappeared from 100% of the northern province reefs and from 60% of the eastern offshore close reefs. It disappeared also from 27% of the eastern offshore remote reefs. No colonies were ever documented in eastern inshore reefs.

Discussion

All of the surveyed coral reefs from northern and eastern Puerto Rico are showing unequivocal signs of declining *Acropora* populations. A combination of natural and anthropogenic factors could have cumulatively and/or synergistically affected their survival and distribution. Acute and highly localized natural factors such as White Band Disease (WBD) outbreaks, patchy necrosis, and predation by the coralivorous gastropod, *Coralliophila abbreviata*, and the fireworm, *Hermodice carunculata*, have been shown to contribute to the demise of *Acropora* spp. from Puerto Rican reefs. High densities of *C. abbreviata* have been also documented on coral reefs with only a few isolated surviving colonies of *A. palmata*. In addition, long-term natural factors, such as damselfish (Pomacentridae) territorial behavior has caused increasing tissue mortality and the pre-emptive outcompetition of corals by filamentous algae. Also, major acute phenomena, such as hurricanes, have caused a widespread destruction of *A. palmata* frameworks and of *A. cervicornis* thickets. Acute and highly localized anthropogenic impacts (i.e., historic coral collection for souvenirs, reef trampling, snorkeling, SCUBA diving, some fishing mehtods) have also caused a major destruction of corals. Also, severe acute anthropogenic impacts have caused major destruction of *Acropora* assemblages, including ship groundings (i.e., Los Corchos, Culebrita, Islote Palominitos) and military activities (i.e., Culebra, Vieques). Finally, major long-term anthropogenic degradation of water quality (i.e., higher turbidity, lower transparency, higher concentration of nutrients and solid suspended material) and higher sedimentation rates have largely contributed to the inshore coral reefs Acroporid corals decline.

Acropora in the U.S. Virgin Islands:
A Wake or an Awakening?

Caroline S. Rogers*, Barry Devine, and Christy Loomis
* National Park Service (USGS), Carribean Field Station
1300 Cruz Bay Creek, St. John, USVI 00830 USA, Caroline.rogers@usgs.gov

Many shallow coral reefs in the US Virgin Islands had impressive, nearly monospecific stands of elkhorn coral (*Acropora palmata*) in the late 1970s and early 1980s. A series of hurricanes and white band disease (first noted in 1973 at Buck Island Reef National Monument) decimated these stands. "Grave-yards" of elkhorn, where detached dead branches of this species are interspersed among dead but standing colonies, are still visible. However, at least at some locations around all three of the major islands, St. Thomas, St. Croix, and St. John, there is evidence that elkhorn coral is recovering.

We have developed a protocol for mapping and assessing the condition of elkhorn colonies based on recording GPS waypoints for each surveyed colony along with data on depth, size, presence of disease and predators, percent dead, etc. Photographs are also taken of each colony, and all data are entered into a database. The GPS waypoints are mapped onto geo-referenced aerial photographs providing information on spatial patterns. Over time, we hope to be able to document if there is an increase in both the number and size of the elkhorn colonies. Our work to date has focused on elkhorn, although we have begun to use the same protocol for *A. cervicornis* (staghorn). Damselfish territories and possibly white band disease have been noted on staghorn corals. While the emphasis is on the corals, recovery of these morphologically complex species will presumably have effects on fishes and other associated organisms and communities, and these relationships should be explored.

Preliminary analysis of data on 279 elkhorn colonies from 5 locations around St. John shows that many of the corals are relatively small and could have become established since Hurricane Hugo (1989) and Hurricane Marilyn (1995). Coral-eating snails were present on about 12% of the colonies surveyed. About 25% of the colonies were partially dead (1 to 85%). No active white band disease was seen.

At Hawksnest Bay, over 300 elkhorn colonies are growing on one patch reef. The protocol is more difficult to use when colonies are in dense stands such as at this site. However, the GPS unit can be used to delineate a polygon around the stand, and at least some of the desired data can be collected.

Storms, disease, predators, and damage from boats continue to cause elkhorn colony mortality. (On April 7, 2002, an 85' ferry grounded on a reef inside Virgin Islands National Park causing extensive damage to living elkhorn colonies). Although this species has many mechanisms for recovering from physical damage, and fragments can develop into new colonies, it is not clear that it will be as successful at recovering from the current assault from an overall, unprecedented combination of stresses (including predation and disease).

Acropora palmata: Historical Status, Extent of Decline, and Projection for Recovery, on St. Croix Reefs

William B. Gladfelter and Elizabeth H. Gladfelter*
* Marine Policy Center, Woods Hole Oceanographic Institution
Marine Policy Center, #41, Woods Hole, MA 02543, egladfelter@whoi.edu

The distribution of *Acropora palmata*-dominated reefs on the St. Croix shelf during the mid-1970s is summarized. These reefs totaled nearly 10 sq. km. in area. Surface coverage (defined as % of projected planar surface area) exceeded 70% in some areas (e.g. the forereef of Buck Island). In this zone there were actually several m^2 of live coral tissue per m^2 of reef due to the layering of branches. By the mid-1980s white band disease (WBD) had devastated populations of *A. palmata* everywhere on St. Croix, and surface coverage had decreased to a maximum of a few percent, but was less than 0.1% in many areas.

Following demise of the *A. palmata* population from WBD, a study was initiated in 1988 on a 200 sq. m quadrat on the eastern forereef of Buck Island to monitor individual coral colonies and to observe initial stages of recovery of the *A. palmata* population in the previously densely populated reef zone. This study plot was subsequently monitored in 1991, 1996 and 2002. In 1988, the population of *A. palmata* in this plot, although enormously reduced, had 5% surface coverage. It appeared to be healthy, recovering from destruction, and no WBD disease was observed. Hurricane Hugo in 1989 caused further reduction of the population to 0.8% in the study plot. Post-Hugo recruitment of *A. palmata* was first observed on the northeastern reefs of St. Croix in 1992, where numerous 10-15 cm high *A. palmata* colonies were observed on Prtzl Reef. Nine former *A. palmata*-dominated reef sites were surveyed in March 2002 to ascertain present coverage and recent recruitment of *A. palmata*, and where data exist, compared to prior coverage during the 1970s, 1980s or 1990s. Size-frequency distributions, densities and % (planar) surface cover were determined for four of these sites: % surface cover ranged from <0.1% for south shore forereefs to 1.4, 2.4 and 3.6% cover for three north shore reefs. The population structure, including the presence of recent recruits, as well as the healthy appearance of the colonies suggest young, healthy and actively growing populations of *A. palmata* on the north shore reefs that, barring devastation by storms, predators, or disease, appear to be on their way to recovery.

The Demise of *Acropora* in the Caribbean: A Tale of Two Reef Systems

W.F. Precht* and R.B. Aronson**
* Ecological Sciences Program,PBS&J, 2001 NW 107th Avenue, Miami, FL 33172
**Dauphin Island Sea Lab, 101 Bienville Boulevard, Dauphin Island, AL 36528

Over the past two decades, coral reefs in the Caribbean have changed dramatically. Reef-building corals have declined, and the cover of fleshy, noncoralline macroalgae has increased. Many authors have argued that the loss of herbivores has been the culprit in the community shift, while others have cited reef nitrification. It is our contention, however, that coral mortality especially the mortality of the *Acropora* is the crucial precursor to macroalgal dominance. For example, ten years after Hurricane Hattie devastated reefs from northern Belize in 1961, the once lush coral community was reduced to a layer of coral rubble covered by fleshy macroalgae. This was identical to the pattern observed on Jamaican reefs more than 20 years after the passage of Hurricane Allen (1980). In Jamaica, mortality of the *Acropora* was caused by storm-induced fragmentation followed by collateral mortality related to predation and disease. At research sites at Discovery Bay on the Jamaican north coast, coral cover has fallen from >50% in the late-1970's to <5% today, while macroalgal populations have risen from near 0% to >60% during the same period.

Acropora cervicornis was also the dominant space occupier at intermediate depths on the fore-reef (8-20 m) along the central portions of the Belizean barrier reef from at least as far back as the 1960's until the mid-1980's. Subsequently, *A. cervicornis* populations collapsed due primarily to mortality associated with white-band disease (WBD). At Carrie Bow Cay the location of the Smithsonian coral reef research station, coral cover dropped from 30-35% in the late 1970's to 12-20% in the 1990's. These losses were followed by concomitant increases in macroalgae (<5% in 1980 to >60% in the early 1990's). Populations of *A. palmata* have been decimated on these reefs from WBD as well.

Combing these ecological data from Jamaica and Belize with other reef areas from throughout the Caribbean reveal similar losses in *Acropora* dominated communities during essentially the same period. On a regional-scale, the mass mortality of Acroporid corals due to a variety of factors and especially WBD has been largely responsible for the present increases in macroalgae. These widespread biotic disturbances, which are still active today, have diminished coral populations, thereby opening space for colonization by algal species. These observations highlight the primacy of coral mortality in general, and disease induced mortally of the acroporids in particular, in changing the face of Caribbean Reefs.

These data also indicate that no form of local stewardship or management could have protected these *Acropora* dominated reef systems from these disturbances or changed the overall trajectory of coral loss. It is becoming increasingly more apparent that regional- and global-scale causes of reef decline are most important in structuring modern reef communities. Understanding the causal link between global change and reef demise are some of our most pressing ecological challenges for the future.

Status of *Acropora* Species on the Leeward Islands of the Netherlands Antilles

M.J.A. Vermeij[1, 2] and R.P.M. Bak[3, 4]

(1) NOAA Fisheries, Southeast Science Center, 75 Virginia Beach Dr, Miami, FL 33149 U.S.A
(2) Caribbean Institute for Management and Research of Biodiversity, Piscaderabaai z/n, P.O.Box 2090, Willemstad, Curaçao, Netherlands Antilles
(3) University of Amsterdam, IBED, P.O.Box 94766, 1090 GT, Amsterdam, the Netherlands
(4) Netherlands Institute for Sea Research (NIOZ), P.O. Box 59, 1790 AB Den Burg, Texel, the Netherlands.

The Leeward Islands of the Netherlands Antilles comprise Curaçao and Bonaire (12° 15' N, 68° 45' W). The islands measure 445 and 288 km^2 respectively and possess a sheltered south coast and a wind-exposed north coast. The oceanic islands lie 60 km off the coast of the South American mainland. Industrial development and immigration resulting in overpopulation during the 1970's imposed a great pressure on Curaçao's terrestrial and marine resources. The reefs of Curaçao are overfished as fish is a cheap source of nutrition. Bonaire remained free of such developments and presently depends on (eco)-tourism (i.e. diving tourism) as the main source of income. A currently effective marine park was established in 1979 protecting the reef to a depth of 60m.

Acropora species formed dominant constituents of the shallow (<10m) reef fauna and were found the entire southwest coast of both Curaçao and Bonaire until the 1981 mass die-off (VanDuyl 1985, Bak and Criens, 1981). The study by VanDuyl (1985) consists of an inventory of the benthic community along the south coasts of both island at a small spatial resolution (<1m^2) and therefore provides an excellent reference to quantify the decrease in *Acropora* cover over the last two decades. In 1980/1981 when the surveys for this work were carried out, *Acropora* species covered 7.94×10^6 m^2 of the reef bottom between 0 and 10m, which corresponds to 15.1 % bottom cover of the shallow reef terrace. Comparing these data with our observations made during the last four years, we estimated the decline in *Acropora* stands to be more than 98%. Local patches remain, however, where *Acropora* patches occurred in large stands covering the entire shallow reef terrace as dense bands (>20m width). These populations occur at exposed sites (i.e. the shoreline faces southeast, which is the direction from which refracted waves hit the island). The importance of water-movement for *Acropora* is also indicated by the north-south gradient that exists in the depth distribution of *A. palmata*. Towards the south exposure to increased water-movement caused (1) colonies to move towards deeper water and (2) branches become thicker and more robust. At extremely exposed sites (i.e. the most eastern tips of the islands) *A. palmata* colonies occur as thin sheets with small branches (<30cm) rising from its surface.

Especially on Bonaire small patches (<60m^2) of *A. cervicornis* occur which seem to be able to survive due to fast growth since they still suffer from white-band disease. Recruitment of the latter species is observed (> 4 individuals m^{-2}) at a few locations cleared by tropical storm Lenny in November 1999 providing solid substratum to settling planulae. The same storm damaged *A. cervicornis* stands at other sites around this island. On the north coasts of both islands enormous patches of *A. palmata* (> 1000m^2) are found and colonies seem unaffected by diseases or high levels of partial mortality (e.g. Boca Patrick). If *A. cervicornis* is also present the supposed hybrid *A. prolifera* (VanOppen et al. 2000) is frequently observed.

Acropora populations have decreased enormously over the last two decades and decline occurred at sites that suffered from increased industrial pollution and sites receiving oceanic water. The occurrence of populations that do well (i.e noticeable recruitment and absence of diseases) shows that these reefs are yet not degraded beyond the point-of-no-return. This indicates that the *Acropora* population at the Leeward Island of the Netherlands Antilles potentially harbors unexpected adaptive (genetic) variation, which allowed them, at least partially, to survive in the present day situation.

References

Bak, R. and S. Criens (1981). Survival after fragmentation of colonies of *Madracis mirabilis*, *Acropora palmata* and *A. cervicornis* (Scleractinia) and the subsequent impact of a coral disease. Proc. Fourth Int. Symp. Coral Reefs, 2: 221-227.

Van Duyl, F.C. (1985). Atlas of the Living Reefs of Curaçao and Bonaire. (Amsterdam: Uitgaven Natuurwetenschappelijke Studiekring).

Van Oppen, M.J.H., Willis, B.L., Van Vugt, H.W.J.A. and Miller, D.J. (2000). Examination of species boundaries in the *Acropora cervicornis* group (Scleractinia, Cnidaria) using nuclear DNA sequence analyses. Molecular Ecology 9: 1363-1373.

Status of Acroporid Populations in Colombia

Jaime Garzón-Ferreira and Juan Manuel Díaz
INVEMAR, Santa Marta, Colombia

According to a recently published base line study of coral reefs in Colombia (Díaz et al., 2000), the total extension of recent coral formations in Colombian maritime areas, both in the Caribbean and the western Pacific, is about 1,090 km^2, of which more than 99% are placed in the Caribbean. In the latter, only 1/3 of the coral reefs are found along the continental coast and shelf, most of them surrounding the offshore islands of the archipelagos of San Bernardo and Rosario. On the other hand, 2/3 of Colombian reefs are found in the oceanic archipelago of San Andrés and Providencia, in the southwestern part of the Caribbean, off the continental shelf of Nicaragua and Honduras. Here, coral formations comprise two barrier reefs surrounding the two major islands, five large atolls, and several coral banks. According to Geister´s typical ecological zonation of Caribbean reefs based on wave exposure zones, which includes a zone dominated by *Acropora palmata* in the highly exposed areas and an *A. cervicornis* dominated zone in medium exposed areas, the base line study estimated the total extension of *A. palmata*- dominated reefs in about 28 km^2 (2.6% of the total coral reef extension) and that of *A. Cervicornis*- dominated reefs in only 0.8 km^2 (0.07%). However, the relative cover of living tissue of both species in their respective zones is very variable from a reef area to another, ranging from nearly 90% in a few scattered patches to less than 15% in the majority of reefs.

Many of the *Acropora* dominated reefs, as they were described in the 1970´s from San Andrés and Providencia are currently reduced to cemetaries of broken skeletons covered by algae. The decline of *A. cervicornis* in this area has been estimated at 99% in the course of the last three decades, and that of *A. palmata* at about 75%. Even worse is the situation in most reef areas along the continental coast. In some areas like the San Bernardo and Rosario Islands, the decline of both species has attained levels of nearly 100%. Only in a few areas, such as Isla Arena and in some bays nearby Santa Marta, scattered small patches or isolated thickets of *Acropora* exhibit living cover over 50% and show even signs of recovery after the widespread mortalities occurred in the course of the last decades. The occurrence of scattered living thickets of *A. prolifera* has been recorded in several places in the Colombian Caribbean, in both oceanic and shelf reefs. A single record of *A. valida* from Gorgona Island off the Colombian Pacific coast has not yet been corroborated but, according to Glynn & Ault (2000), although the record may have been valid, this species appears to be now extinct in the eastern Pacific.

Two detailed studies about the status and health of *Acropora* reef habitats have been performed very recently in the Colombian Caribbean. One of them was carried out in May-December 2001 at several bays of the Tayrona Natural Park (TNP; central part of the northern coast of Colombia, continental reefs) and included mapping of all *Acropora* formations as well as assessments of their current composition, cover, health, and growth rates (Moreno-Bonilla et al, 2002.). The other evaluated only *A. palmata* populations within different geomorphological units of the San Andrés island reef complex (SAI; southwestern Caribbean, oceanic reefs), in January 2002 (Rueda and Acosta, 2002). Preliminary analysis of the results show that cover of reef surfaces at both *A. palmata* and *A. cervicornis* formations of the TNP are now strongly dominated by algae (means 80.6% and 79.4% respectively), while mean live coverage by these corals is very low (9.9% and 5.1% respectively). Average cover of live *A. palmata* in SAI is greater (14%), with a highest mean value in the fore-reef terrace (19%) and the lowest in the

lagoon terrace (5%). In the TNP the ratio of live:dead coral is about 1:14 in the case of *A. cervicornis* and 1:7 in the case of *A. palmata*, based on cover estimates. This relationship is about 1:2 for *A. palmata* in SAI, based on volume estimates. Live populations of *A. palmata* and *A. cervicornis* in the TNP show a high incidence of partial mortality(29.7% and 58.8% respectively), *Stegastes planifrons* territories (55.8% and 58.1%) and *Coralliophila abbreviata* (22.3% and 51.2%). White pox disease is also frequent (18.1%) there in *A. palmata*, while algae overgrowth (72.5%) and fragmentation (54.4%) are common conditions in *A. cervicornis* as well. Partial mortality in SAI is found affecting about 2.7% of the *A. palmata* tissues, associated in part with bleaching, white pox disease and white patches. Linear growth estimates in healthy colonies of the TNP resulted in mean rates of 7.52 cm/year for *A. palmata* and 9.62 cm/year for *A. cervicornis*.

All three Caribbean *Acropora* species have been listed recently in the "red book" of threatened marine invertebrates of Colombia by a technical commission coordinated by the Ministry of the Environment (Mejía et al., 2002). *Acropora cervicornis* was considered as a critically endangered species in Colombia, while *A. palmata* was included as endangered, and *A. prolifera* as vulnerable, according to the IUCN categories.

References

Díaz, J.M.; L.M Barrios.; M.H. Cendales; J. Garzón-Ferreira; J. Geister; M. López-Victoria; G.H. Ospina; F. Parra-Velandia; J. Pinzón; B. Vargas-Angel; F.A. Zapata and S. Zea. 2000. Areas coralinas de Colombia. INVEMAR, Santa Marta, Ser. Publicaciones Especiales 5: 175 p.

Mejía, L.S.; J. Reyes; G. Navas and N. Ardila. 2002. Libro rojo de invertebrados marinos de Colombia. INVEMAR, Santa Marta: in press.

Moreno-Bonilla, M.E.; M. Valderrama and J. Garzón-Ferreira. 2002. Estado actual y crecimiento de las especies coralinas A*cropora palmata* (lamarck, 1816) y A*cropora cervicornis* (lamarck, 1816), en el Parque Nacional Natural Tayrona, Caribe colombiano. INVEMAR, Santa Marta: in preparation.

Rueda, P. and A. Acosta. 2002. Aspectos demográficos, morfológicos y estado de salud de *Acropora palmata* en el complejo arrecifal de la Isla de San Andrés, Caribe colombiano. Universidad Javeriana, Bogotá: in preparation.

Status of the Acroporid Coral Species in the Dominican Republic

Francisco X. Geraldes

Centro de Investigaciones de Biología Marina, Universidad Autónoma de Santo Domingo,
Santa Domingo, Dominican Republic

Description of Coral Reef Areas

Most coral reefs of the Dominican Republic are fringing reefs. There are also two barrier reefs, numerous patch reefs, and four large offshore banks. In the eastern and northwestern coasts, broad coastal shallows platforms with barrier reefs are found, while in other places terrigeneous sediments produce high turbidity that prevents reefs from forming or growth. The increasing coastal development, pollution, untreated wastewater discharges and beach erosion have impacted living reef sites. Following is a report on the status of Acroporid species in the Dominican Republic.

Offshore Banks
The Silver Banks, Atlantic Ocean.

This is a shallow oceanic rise extending 3,740 km2. In it's northern portion a barrier reef has formed, composed of a series of patch reefs bound together near the surface, and extending some 30 km southeasterly. On its protected side, corals grow in column-like structures of cemented skeletons that ascend from the rubble and sandy bottom to the surface some 15 to 25 m upward. *A. palmata* is found occupying the top portion of these columns, as well as in the reef down to 6 m.   The Acroporids found here are in bad conditions. The reef crest panorama is of a skeletal web of dead colonies of *A. palmata*. In places during 1984, there used to be large colonies of *A. palmata* (3 m tall), and dense growth of *A. cervicornis*, there is now rubble grounds around dead stands of palmatas. Turf algae, Rhodophytes, as well as Cyanobacter complex, and encrusting boring sponges grow on top of these remains. The recuperation of acroporidae in this reef is slow. In 1994 reports were received that *A. cervicornis* was budding, as well as the black sea urchin *Diadema antillarum* was reappearing.

Parque Nacional Montecristi Barrier Reef

Located in the northwestern coast, it is the largest reef of the country with 64.2 linear km. The coast is low-lying mountainous terrain of sedimentary origin, in a dry climate setting. The shoreline is almost all covered with red mangroves, followed by seagrass beds and several pocket beaches. This setting is protected by a barrier that varies in distance from shore (200 m to 3,000 m). The reef setting is varied, with high relief features and large living coral colonies are common with sizes exceeding 10 m in diameter.

Reef Lagoon

Coral patches (5 to 800 m2) are found with soft coral, associated mainly with *Montastraea annularis* complex and other rounded forms. Here *A. cervicornis* thrives.

Reef Flat and Back Reef

In areas closer to tidal channels the dominant species are *Porites* sp., and rounded forms. Nevertheless, *A. cervicornis*, *A. palmata*, and *Millepora complanata* are common.

Reef Crest

Skeletal remains of acroporids, poorly lithified, form the reef crest. A few young *A. palmata* can be found, but *Millepora* sp. is the dominant species. On the seaward side the basal structure of the crest is formed by large skeletons of *A. palmata* and *A. cervicornis*.

Outer Reefs

In exposed areas, there is evidence of a lower Palmata zone consisting mostly of large dead colonies of *A. palmata*. To deeper waters *A. cervicornis* is also found in good shape, growing in tidal channels through-out the extension of the reef.

Punta Rucia Offshore Keys

These keys are away from any terrigenous influences and freshwater discharges. In the breaker zone the dominant species found here are *A. palmata*, *Millepora* sp., *Montastraea annularis* complex, and *Diploria strigosa*. On the frontal reef at 12 m depth, a diverse coral community can be found were *A. palmata* stands among other species

Reefs Along the Reef Terraces of the Dominican Republic, (Atlantic Ocean)

Most of the coastline area are facing the easterly trade winds and its oceanic condition. The littoral zone drops abruptly to deeper waters (2-10 m). The bottom is composed of eroded carbonate rocks, covers by encrusting algae, and species adapted to harsh environs. The coral growth can include *A. palmata* forming small patches   In the deeper sandy areas, small patches of *A. cervicornis* can be found. Most of the sites visited have presented these species coming back in association with healthy *Diadema antillarum* populations.

Fringing Reefs of Dominican Republic, (Atlantic Ocean)

The traditional land use has been agriculture. Recently tourism has increased coastal settlements near reef sites and beaches. The predominant reef structures are coral patches with low cover and few living corals. The few fringing reef of *A. palmata* and *Porites* sp. are now affected *A. palmata* skeletal are found covered with algae and sediments. *Millepora* sp. has since dominated the breaker zones. Nevertheless, the acroporids in the deeper water are still healthy.   Another type of coastal feature is of intrusive igneous mountain slopes and terraces. The climate is very humid; the forest cover has turned into agricultural fields. The reefs here are of the fringing type very close to shore and in shallow waters where reef patches can be found. These are composed of skeletal remains of *A. palmata* covered by algae and sediments. On outer reefs, approximately 5 miles offshore shoals (15 m deep) of eroded carbonate terraces are found, with few corals species, but no acroporids.

Reefs at the Mona Passage of Dominican Republic

In the east facing the Mona Passage, is the Bávaro-El Macao-Punta Cana Barrier Reef System, extending almost continuously for 60 km. The coastline is sandy, followed by mangroves, coastal lagoons, and swamps. The reef lagoon can be as wide as 3.5 km (2-5 m deep) and typically has coral patches and seagrass beds. In the back reefs *Porites* sp., rounded forms and *A. cervicornis* are common species. *A. palmata* skeletons covered with algae in association with *Millepora* sp. dominates the windward side of the breaker zone, which is narrow and steep. At 4 m, there are large dead stands of *A. palmata* as well as large boulders of *Montastraea annularis* complex, and *Diploria* sp. In some sites, the breaker zone can be narrow and composed of very large compacted skeletons of *A. palmata* where algal cover is high and few live corals are present.

Reefs of Parque Nacional del Este

The reefs of this protected area are basically low relief systems, found either as fringing and small deep (20-30 m deep) patches. Most of them are in the leeward side protected by a landmass of Pleistocene and Recent reef terraces.

Fringing Reefs

At the 10 m contour the bottom is covered with skeletons of *A. palmata* which project to the surface. At the reef crests there are live colonies of *A. palmata*, *A. cervicornis*, *M. complanata*, and rounded forms. Sporadic coral congregations turn the narrow reef flat and converts itself into an *Acropora - Montastraea* zone, forming the breaker. The acroporids in the breaker zones are not very healthy mainly due to recent storms. At depth > 3 m, there are large colonies of *A. palmata*, in varying health conditions.

Low Relief Spur and Groove Communities

Here it is common to find large dead colonies of *A. palmata*, and underneath them, some broken branches with new growth. The presence of *D. antillarum* is noticeable. In several places new growth of *A. cervicornis* is commonly found.

Reefs of Parque Nacional del Este
Hard Bottom Carbonate Reef Flat Communities

In terms of diversity, they are dominated by turf and brown algae, and/or a co-dominated by algae and corals. The corals are more diverse in these communities, with 12 species, the most common being *A. palmata*, *Diploria clivosa*, *Porites astreoides*, and *Porites porites*.

Patch Reef Communities

These are located in protected waters on the western portion of the leeward side or inside the Catuano Passage, protected by the fringing reef and it's reef crest. In some cases *A. cervicornis* is found. Large (>2 m diam) colonies of *A. palmata* that serve as base structure for other species to settle are also found.

Fringing Reefs of the Southern Pleistocene Reef Terraces of the Dominican Republic (Caribbean Sea)

The southern coast has four major coastal features: Pleistocene reefs terraces, medium size river estuaries, shallow carbonates platforms, and terrigenous substrates. Reef formations can only be found in the shallow carbonates platforms, forming fringing systems. In the late 1980's, most of the fringing reefs associated with sheltered white sandy beaches have been used by the tourism industry and its secondary development, altering the natural settings. The breaker zone of these areas is very stressed and is now largely formed by dead loose remains of *A. palmata* and rounded forms covered by turf algae and sediments. The lower Palmata zone has also been affected receiving large amounts of sediments coming from the heavy activities that occur at the beach and lagoon regions of the reefs. At deeper sites (12 m), the reef is in good shape, including the acroporids found there.

Fringing Reefs of the Pleistocene Reef Terraces of the Dominican Republic (Caribbean Sea)

At the spur and groove formations in the base of the breakers zones (4-6 m deep), large colonies of *A. palmata* and *Montastraea annularis* complex still dominates, surrounded by several other species. Approximately 30% of the *A. palmata* (at Boca Chica site) withstood the Acroporid mortality event. Nevertheless, the seascape seems catastrophic, finding pieces of corals encrusted with algae and sponges littering the bottom. Between all this, small colonies of *A. palmata* appear. In deeper waters, at 20 m, a striking growth of *A. cervicornis* and other species can be found.

Fringing Reefs of the Terrigenous Southern Coast of the Dominican Republic. (Caribbean Sea)

In the sedimentary loose terrains this coasts lies in a dry climate setting, but several medium size rivers discharge in the region. Since mid 1980's, agricultural irrigation programs have altered this natural setting.

Places were reef developed, now have been transformed into estuarine zones. Waters are loaded with agricultural by-products, pesticides and fertilizes, as well as high with sediment loads. This situation has practically eliminated all of the standing live corals and reefs in the region. It is now rare to find living stands of *A. palmata* and *A. cervicornis*. Is also suspected that conditions for the rare *Acropora prolifera* are now gone. (Puerto Viejo reef is one of a few sites were it has been reported for the Dominican Republic).

Parque Nacional Jaragua

Parque Nacional Jaragua is located at the southwestern portion of the Dominican Republic in very dry climate. No rivers or surface runoff is found in these Pleistocene reef terraces. On its leeward coast, protected by high cliffs, sheltered long and white sandy beaches are common, followed by consolidated hard carbonate substrate where coral cover and density is high. There is not a well-developed fringing or bank reef in most of the zone, *A. palmata* is not a common species in this settings.

Development, Sedimentation, and Water Quality

It has inflicted major changes in the reef setting due to: deforestation, coastal urban development, dredging, agriculture irrigation projects, industrial development, and wastewater deposition without treatment.

Coral bleaching, mass mortalities, and other stresses.

There has not been a countrywide study of bleaching for the Dominican Republic. However, reports of its occurrence is more evident at the reef sites near major urban settlements, as well as those reefs which are more heavily visited or over fished such as: Puerto Plata, Sosúa, Las Terrenas, Macao, Bávaro, Guayacanes, Boca Chica, and La Caleta. The mass mortalities of *A. palmata* and *Diadema antillarum* were reported, as have been rare occurrence of coral and octocoral diseases.

Hurricanes and tropical storms.

Hurricanes and tropical storms are natural events common in Hispaniola. There have been more than 200 of these events recorded since the 15th century. These phenomena are more common for the Caribbean southern coast, rarely affecting the Atlantic coast. Nevertheless, all major reef sites have been affected by at least one of these events.

Overfishing

Overfishing is believed to be one of the major causes that has prevented the comeback of Dominican reefs. Overharvesting of commercially important species such as S*trombus* sp., *Panulirus* sp., and fishes of the Serranidae, Lutjanidae, and Scaridae families, is evident. Lately, there has been an increase in the harvesting of other reef creatures such as black corals, hermit crabs, ornamental reef fishes, starfish, sea urchins and live rocks for the souvenir and aquarium trade. In these later cases it has been introduced the use of chemical substances such as Clorox bleach, among others to harvest the ornamental species. This is affecting the corals and other non-target species as well.

Recent Legislation

Most of the activities related to non sustainable fishing practices, as well as industrial, agricultural and rural development, mentioned above, have been either prohibited or regulated by the recently promulgated Environmental Law 64/00 and several Presidential Decrees. Nevertheless the marine ecosystems management is not receiving the sufficient financial and political support needed to support and implement the mandates and policies, enforcement and education.

Status of Acroporids in the Mexican Atlantic

Eric Jordán-Dahlgren
Laboratorio de Arrecifes Coralinos
Estacion Puerto Morelos, ICMyL, UNAM
Ap. Postal 1152, Cancun 77500, Q. Roo. MEXICO

Foreword: I have had the luck to be able to visit most, if not all, of the reefs in the mexican Atlantic at least twice in my coral reef researcher career, some 20 years now. This allow me to have an spatial overall view, but also some idea of trends, as comparative assessment of coral community structure has been one of the main tools of my work. I have to said this, so that you would be able to understand the background from where I am expressing my views regarding Acroporids status in Mexican reefs.

Coral Reef Distribution:

Coral reefs in México can be roughly grouped in three sets at the geographical scale: 1) SW Gulf of México reefs; 2) Campeche bank reefs, and 3) Caribbean reefs.

The SW Gulf reefs are close to shore (from 0.5 to 11.7km) and comprise three main reef sets (Veracruz-Antón Lizardo, Tuxpan and Isla Lobos reefs; Fig. 1) forming clusters of relatively proximal reefs; rising from depths of 25 to 35m and with shallow lagoons. These reefs are strongly influenced by large river discharges, carrying large amounts of suspended sediments and a wide array of pollutants. Campeche bank reefs are well-developed isolated banks lying 80 to 130km offshore in an oceanic climate far from terrestrial influences. Morphology among all these reefs varies widely. Along the Mexican Caribbean "extended fringing reefs" (barrier –like reef tracts separated from the coast by a well developed, but shallow lagoon) dominate the continental margin and the largest atoll-like reef in the Caribbean: Chinchorro reef is found on the southern section. Continental influence upon Caribbean reefs is negligible because the Yucatán peninsula is a karstic platform where rivers are mostly absent.

Acroporids distribution in the Mexican Atlantic:

Acropora palmata, *A. cervicornis* and *A. prolifera* are pan-Caribbean species and can be found any-where in the region. This section therefore, addresses the reef areas or reef structures characterized by the ample dominance of any of these species.

1) SW GULF OF MÉXICO REEFS

Most reef in the Veracruz-Antón Lizardo reef system (southernmost SW Gulf reefs), had an extremely well developed *Acropora palmata* belt in the shallow windward forereef zone, from the reef crest down to 5 or 6m. Such belts were composed by monospecific, dense and continuous stands of very large colonies with a growth form typical of relatively high-energy environments. Northward, at Tuxpan reefs these *A. palmata* belts decrease in importance, although are still present. At Isla Lobos reefs the belts disappeared, and mostly scattered *A. palmata* colonies dominate the shallow, windward forereef.

In the leeward margin of many of these reefs very extensive beds of *A. cervicornis* could be found, as well as in some shallow protected areas.

Mortality:

Around the early 1970´s extensive mortality in the windward *A. palmata* belts and the leeward beds of *A. cervicornis* was evident by the mid 1970´s most of these colonies, if not all, have died. Their skeletons remained *in situ* in standing position.

Actual Status (Recovery):

Recovery is very limited, restricted to ends of reefs by the early 1990, but occurring in most of the SW Gulf reefs (Jordán-Dahlgren, 1992). Interestingly *A. palmata* recovery occurred mostly by "re-sheating" of new tissue over standing skeletons of the same species. This process consist of new tissue growth over large areas of a dead skeleton, without producing new branches, actually re-sheeting the old skeleton. Apparently, it happens with both surviving tissue (re-growth in this case) in a mostly dead colony and/or when a sexual propagule recruits to the dead skeleton (Jordán-Dahlgren, 1992). A phenomenon that we have witnessed in many instances afterwards.

By the year 2000 recovery is still relatively minor in these reefs, and a subjective estimation would be an increase on the order of 3 to 5% in living *A. palmata* cover, with high local variability. In Tuxpan reefs recovery had been apparently more widespread than at Veracruz-Antón Lizardo, but unfortunately locals had been extracting many of the new small colonies for souvenirs and trade. Recruits that undergo re-sheating are less affected by this practice.

2) CAMPECHE BANK REEFS:

A. palmata and *A. cervicornis* are important species in the shallow exposed and protected areas of most of these reefs. Logan (1969) describes massive stands of these two species in many Campeche bank reefs. My personal observations indicate that *A. palmata* formed belts (as described above) mostly in the semi-protected northern, and at times also, in the southern tip of these reefs. In protected areas *A. palmata* forms many inner and at times large patch reefs. The eastward shallow fore reef has been mostly barren of Acroporids during my observations. Also in protected areas, either inner or leeward, very extensive stands of *A. cervicornis* were common, from 25 to 30m deep to very shallow areas, even in the reef flats.

Mortality:

At an unknown period most of the *A. palmata* and *A. cervicornis* suffered massive mortalities in these reefs. The *A. palmata* skeletons have remained mostly *in situ* in standing position, but the *A. cervicornis* beds are now mostly gravel deposits.

Actual Status (Recovery):

Recovery is still limited, but evident in many reefs. We have quantitative data from 1995 and 2001, for two separated Campeche reefs, and clearly *A. palmata* is recovering at good rate wherever it occurs, both by re-sheeting and by new colony recolonization (data is still being processed). Recovery is not homogeneous in reefs areas or zones, instead is highly patchy. *A. prolifera* is relatively abundant in some shallow areas of these reefs. *A. cervicornis* seems to recover more slowly than *A. palmata.*

3) CARIBBEAN REEFS

A. palmata dominates the shallow reef environment along the reef tract. In many areas *A. palmata* reefs are highly conspicuous, like in the Siyan Ka´an biosphere area (Jordán-Dahlgren at al. 1994). But the condition and extent of the species stands varies widely (Jordán-Dahlgren, 1993). *A. cervicornis* was relatively abundant in the shallow protected areas along the reef tract some 20 to 15 years ago, but is a rare species nowadays. *A. prolifera* is not common, although at places is relatively abundant.

Mortality:

From the 1970´s to the late 1980´s *A. palmata* and *A. cervicornis* suffered mass mortalities in the mexican Caribbean reefs. *A. palmata* however, was never massively destroyed as relatively large areas of healthy stands alternated with areas of total mortality. Particularly in the central and southern parts of the reef system. This is in contrast to what may to have occurred in the Campeche Bank and SW Gulf reefs, where the Acroporids demise was overwhelmingly uniform. In the NE section of the coast *A. palmata* survived quite well, but no so *A. cervicornis* whose former large stands have disappeared from the time being. In 1988 the very large Hurricane Gilbert (also class V) landed in the NE coast and destroyed most of the *Acropora* stands.

Actual Status (Recovery):

We only have reliable data for the NE Yucatán coast. But it now shows a fast pace of recovery after a long period (3 to 4 years) of no apparent recovery. Recovery is taking place in a highly patchy pattern where re-sheeting dominates recovery of old stands and by new colony colonization in many areas where prior to Gilbert hurricane there were no *A. palmata* stands (Jordán-Dahlgren and Rodríguez-Martínez, 1998). Other areas that used to have luxurious *A. palmata* stands, are still large piles of rubble, with no signs of recolonization. *A. cervicornis* is also becoming less rare, but still is in a phase

DISEASES:

Although recovery in terms of Acroporid cover seems to be well underway in some reefs, is still too early to address if full recovery in terms of dominance and covered reef area would be achieved anytime soon. Disease may slow the recovery process (white- band disease may be responsible for the demise of *Acropora* in the Caribbean), as many of the new colonies had signs of diseases such as white band and some colonies show necrotic patches (Rodríguez-Martínez et al., 2001). Data are still being collected and processed, but I may say now that at some reef sites, diseases are having a serious populational impact in the recovery process, whereas in others the effect seems to be reversible and still in others is negligible.

Fig. 1 Map showing reef localities in the Mexican Atlantic
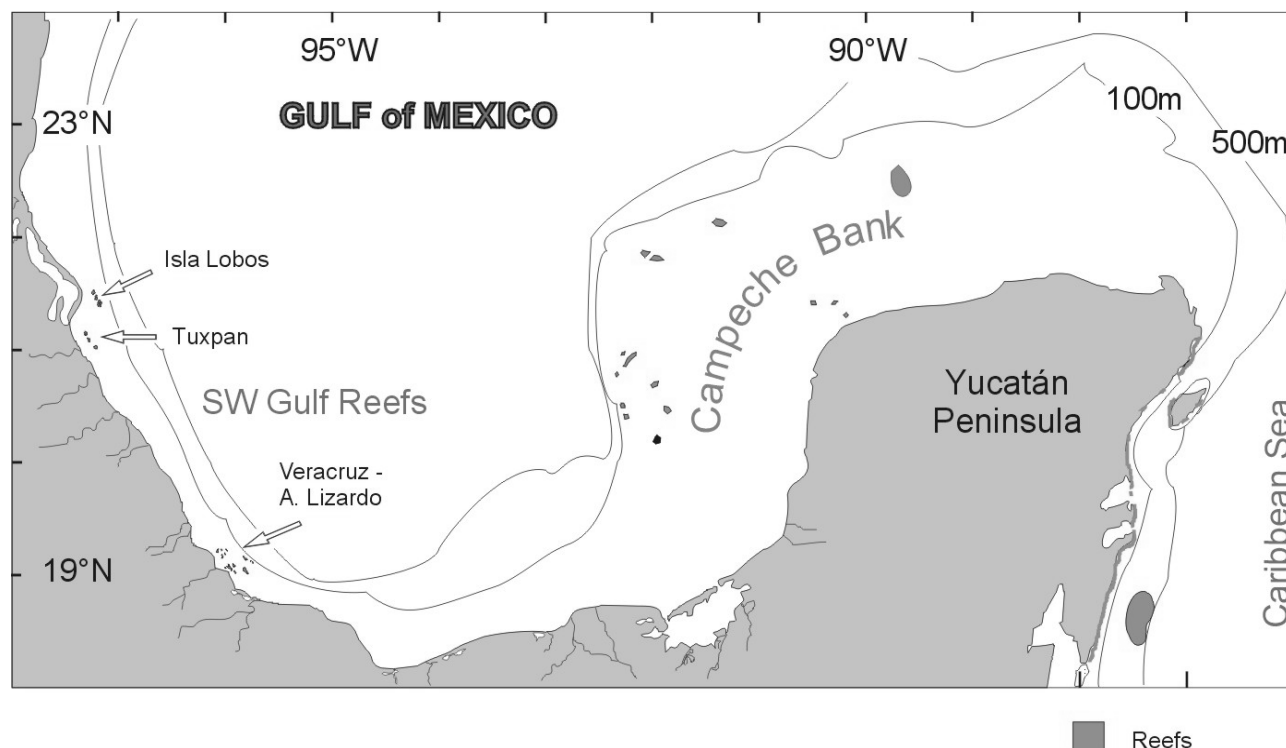
References

JORDÁN-DAHLGREN, E. 1992. Recolonization patterns of *Acropora palmata* in a marginal environment. Bulletin of Marine Science, 51(1): 104-117.

JORDAN-DAHLGREN, E., 1993. Atlas de los arrecifes coralinos del Caribe mexicano. Parte I, El sector Continental. Editado por CIQRO e ICML, UNAM. CIQRO, 114 pp.

JORDÁN-DAHLGREN, E., E. MARTÍN-CHÁVEZ, M. SÁNCHEZ-SEGURA and A. GONZÁLEZ DE LA PARRA. 1994.   The Sian Ka'an Biosphere Reserve Coral Reef System, Yucatan Peninsula, México. Atoll Research Bulletin 423: 1-19 (m s figuras).

JORDÁN-DAHLGREN E. Y R. RODRÍGUEZ MARTÍNEZ, 1998. Post-hurricane initial recovery of A*cropora palmata* in two reefs of the Yucatán Peninsula, México. Bulletin of Marine Science 63(1): 213-228.

RODRÍGUEZ-MARTÍNEZ, R.E., BANASZAK, A.T., E. JORDÁN-DAHLGREN, 2001. Necrotic patches affect *Acropora palmata* (Scleractinia:Acroporidae) in the Mexican Caribbean. Diseases of Aquatic Organisms 47:229-234.

Mapping Marine Populations

Barry Devine, Ph.D., Chief Scientist; Christy Loomis, Data Manager
Conservation Data Center, University of the Virgin Islands
and
Caroline Rogers, Ph.D.
Marine Ecologist, United States Geological Survey, Virgin Islands Biosphere Reserve

Landscape pattern analysis of the distribution of biological populations and community types has been well developed for terrestrial mapping for some time. Global Positioning Systems (GPS) are used routinely to provide accurate maps and locations of point and polygon features that can be imported into a GIS platform. The principles of landscape ecology and the study of ecosystem structure and change are being explored to understand the link between landscape pattern and ecosystem function. In the marine environment, mapping populations of organisms and understanding seascape patterns are considerably more difficult as a result of technical, equipment, access, depth, and visibility problems.

This presentation will describe a simple new Surface Water GPS methodology for mapping shallow reefs and near coastal species distributions. A group of partner agencies in the Virgin Islands; UVI, USGS and NPS, have worked to develop a low tech method of geo-referenced mapping in coastal waters. This technique is presently being used to map the distribution of Acroporid species, including size, depth, snail predation, disease and % live coral cover.

Using existing technology and adapting it to marine circumstances, highly accurate population distribution maps can be overlayed on digital images and benthic habitat maps creating the first maps of marine populations. A Garmin 12XL GPS unit placed inside an Aquapac waterproof case and attached to a small kickboard float is towed by a snorkeling swimmer. After locating a species of interest, a mark is made for a GPS waypoint and saved. Other field personnel record a digital still or video image and data about the colony is recorded on a standard field sheet.

After collecting both waypoint and track positions, the GPS is brought to the office where the track and waypoints are downloaded, converted to a textfile where data fields are added and then converted to a dbf file for import into Arcview GIS. This methodology opens a new approach to marine mapping by providing position data capable of being used at the scale of the local population to track change or recovery over time.

"Unprecedented" *Acropora* Die-Offs: 6,300 & 3,000 ybp

Dennis Hubbard,
Dept. of Geology-Oberlin College, 52 W. Lorain St. Oberlin OH 44074

In 1992, Jeremy Jackson observed that Pleistocene coral reefs exhibited general spatial stability. In contrast, monitoring and anecdotal observations have documented short-term variability and decline in reefs over recent decades. The result is an increased interest in the fossil record as a "pre-anthropogenic" frame of reference for conditions today. Proposals that recent disease outbreaks are "unprecedented" and largely anthropogenically induced are becoming increasingly common. This position requires three assumptions. First, changes in reef-community structure over periods of decades (i.e., monitoring records) can be identified in the fossil record.   Second, spatial continuity of species and reef zones in the Pleistocene reflects uninterrupted temporal stability.   Finally, examples of community disruption on the scale of the recent decimation of *Acropora* by white-band Disease do not exist in the Holocene record.

Cores through the shelf-edge reef communities off St. Croix, Puerto Rico and Florida reveal active *Acropora*-reef development starting around 10,000 ybp and ending suddenly between 7,000 and 6,300 ybp at all three sites. This is associated with a dramatic decrease in the number of *A. palmata* samples reported in the literature. Cores from a reef around Buck Island (U.S. Virgin Islands) reveal a species composition similar to that seen in monitoring records prior to the onset of WBD, implying that the "average" forereef community over the past 7,000 years was similar to what existed there before disease decimated *A. palmata* throughout the region. At 3,000 ybp, however, Acroporids disappeared at Buck Island, and community dominance shifted to massive corals. This corresponds to a second interval during which no *A. palmata* samples have been reported in the literature. While the overall pattern of reef development better matches the pre-WBD community at Buck Island, a more detailed look at the record implies a second Caribbean-wide interruption in the *A. palmata* record. Thus, spatial persistance is not necessarily equivalent to temporal continuity. Our cores have documented at least two regional gaps in the *A. palmata* record that appear analogous to the recent near-extirpation of the species by WBD. A re-examination of our new found confidence in separating natural from anthropogenic change seems in order.

Population Dynamics and Life-History Traits of *Acropora palmata*: Costs and Benefits of Fragmentation

Diego Lirman, Ph.D.
Assistant Scientist, Center for Marine and Environmental Analyses
Rosenstiel School of Marine and Atmospheric Science
University of Miami, 4600 Rickenbacker Cswy., Miami, FL 33149
Email: dlirman@rsmas.miami.edu

Several unique characteristics differentiate *Acropora palmata* from other coral species. Although *A. palmata* can be very susceptible to the physical disturbance caused by storms, it can also exhibit extraordinary regeneration and regrowth capabilities. The ability of *A. palmata* to form new colonies from storm-generated fragments, together with the reportedly low success of sexual recruitment in this species, suggest a strong connection between storm disturbance and survivorship and persistence of this species.

Here, I present the results from a simulation model developed to test the potential impacts of physical disturbance on elkhorn populations. This stage-based transition model identifies storm intensity and frequency as important factors influencing damage and recovery patterns of *Acropora palmata* populations. The simulations highlight an important trade-off between the primary and secondary negative impacts of storm damage and the need for this species to propagate asexually in light of its limited sexual recruitment success. After a severe storm, *A. palmata* populations can be numerically dominated by fragments and crusts. The shift in biomass from units with high survivorship (i.e., colonies) to units with higher mortality probabilities (i.e., fragments and crusts) can affect the recovery and long-term survivorship of disturbed populations.

Clearly, the difference between a storm being a destructive force or an external factor that promotes asexual propagation and population expansion is often a small one, and the balance between these two will ultimately influence the long-term survivorship of *A. palmata* populations already decimated by diseases and other stressors.

Genetics of *Acropora cervicornis*

Steve Vollmer,
Harvard University, 16 Divinity Ave. , Cambridge, MA 02138, svollmer@oeb.harvard.edu

Since I am unable to attend the meeting, I thought I would summarize what the genetics of Caribbean *Acropora* says about the system and how this information might add to the conservation of *Acropora cervicornis*. Basically, I see three major questions that the genetics of *A. cervicornis* can answer: 1) Is *A. cervicornis* a discrete species (or evolutionary lineage), 2) How much gene flow exists between populations of *A. cervicornis* and what is the scale of any connectivity, and 3) How much genetic diversity exists within local populations and how may this relate to the corals ability to survive perturbations like bleaching, white-band, etc.?

1) The genetics clearly shows the three Caribbean *Acropora* (in review) are a natural hybridization system with *A. prolifera* being a morphologically variable, first generation hybrid of *A. palmata* and *A. cervicornis*. We have taken to calling *A. prolifera* immortal mules for their potential to propagate clonally through asexual fragmentation. Introgression is limited by hybrid infertility or inviability, but rare backcrossing of *A. prolifera* with *A. cervicornis* allows for the some mtDNA and nuclear introgression. For *A. cervicornis*, this means that its genome is likely sprinkled with *A. palmata* genes, and, while introgression in general appears rare, its extent is unknown at present. Surprisingly, introgressed mitochondrial haplotypes in *A. cervicornis* are quite common (ca. 20%) and distributed throughout the Caribbean, even though backcrosses occur ca. 1 every 10 generations. An important distinction for the status and conservation of *A. cervicornis* is that the genetic data show it is a distinct species or genetic lineage, despite this introgression. The gene flow between the species constitutes an interesting avenue of species research (which we are actively pursuing), but the introgression is functionally not affecting the independent evolutionary trajectory of the species. I would be happy to discuss this research with anyone interested at length via email (etc.) and/or furnish a copy of the manuscript in review once it comes out of its current state of limbo (hopefully soon).

2) We are also looking at the population structure and connectivity of *A. cervicornis* across the Caribbean using the markers (mtDNA control region in particular) that we have developed for the hybridization work. Preliminary data suggests population structure among islands and potentially even over small spatial scales (ca. 20kms). We are actively gathering this data, and would appreciate any samples especially from the southern Caribbean. This result is somewhat surprising, and has important conservation implications – namely that each population should be considered individually with the best potential for recovery coming from local populations and not larvae drifting in from afar. To me, it also suggests that any transplant studies should occur (when possible) with fragments from nearby populations since there may be potential for local adaptation that should be preserved. However, given the state of some populations, this may no longer be possible.

3) One major focus should also be on the amount of genetic or clonal diversity within populations. In Puerto Rico, we are finding surprisingly high levels of genetic diversity at some sites (ca. 1 genotype per 5m), whereas other sites appear to be dominated by a single clone. We are gathering similar data from sites in the Bahamas, Jamaica, and Panama. Amounts of genetic diversity in local populations has important evolutionary and ecological implications which we can discuss further. Some fruitful areas of research might be to see if genetic diversity correlates to a population's ability to survive perturbations like bleaching. We

are hoping to pursue these and related avenues with our approach. Yet, it could also be argued that populations are already perturbed given the white band epidemic. Nevertheless, I suggest that consideration should be given to this issue and any conservation strategy (esp. transplants) should take into account preserving meaningful genetic diversity.

I will stop here and conclude by saying, in my biased opinion, that including genetics will add greatly to any conservation strategy for *A. cervicornis*. Getting a very gross fingerprint of these corals (with PCR, sequencing, and RFLP) could be easily adapted for these purposes.

Genetic Status of *Acropora palmata* Populations in the Caribbean

Iliana B. Baums

University of Miami, RSMAS-MBF, 4600 Rickenbacker Causeway,
Miami, FL 33149 ibaums@rsmas.miami.edu

Acropora palmata populations showed a significant Caribbean-wide decrease in the 1980s together with their congener *A. cervicornis* and are still in a depressed state. It has been suggested that white-band disease (WBD), a disease specific to Acroporids (Antonius 1981; Gladfelter 1982; Peters 1993) is the primary cause of the recent mortality observed in wide areas of the Caribbean. It might have served as a strong selective agent, i.e. killing non-resistent genotypes and thereby reducing genetic variability. Additionally, Acroporids are particularly susceptible to hurricane breakage and have undergone major bleaching events in the last decade.

Clonal structure

A. palmata reproduces both sexually and asexually. Asexual reproduction can be the dominant mode of reproduction (Highsmith 1982). The high Acroporid cover of Caribbean reefs prior to the 1980s resulted from the combined effects of fragmentation and high growth rates.

Asexual reproduction leads to the multiplication of a particular genotype and results in an assemblage of genetically identical individuals that can function and survive on their own (Carvalho 1994), called a clone. Asexuality per se has no effect on allelic or genotypic frequencies in populations. It does not allow for genetic segregation and recombination, however, and so preserves the effects of selection, genetic drift, or founder effect on the genetic diversity. Bak (1983b) hypothesized that high asexual reproduction rates led to low genotypic diversity so that Acroporids were more susceptible to disease compared to non-branching species.

A. palmata reproduces sexually by releasing egg-sperm bundles in the water (broadcast spawning, Szmant 1986). Larvae settle out after about 1-2 weeks in the plankton. The pelagic life stage provides the opportunity for long-distance transport of larvae with the surface currents (Sheltema 1977; Crisp 1978).

The dominance of asexual reproduction combined with broadcast spawning has implications for the recovery potential of declining *A. palmata* populations. The breeding population size reaches its maximum if all genets contribute to the next generation. *A. palmata* is expected to have a small breeding population size: both fertilization success of spawned gametes and the recruitment of larvae is highly stochastic and dependent upon local conditions. By chance, only a few individuals might contribute a large number of offspring to the next generation (sweepstake effect, Hedgecock 1994a, b). Once colonies become rare, the distance between them might limit fertilization success (Allee effect) even further. Populations with small breeding population sizes are far more prone to extinction due to demographic stochasticity, reduction in gene diversity, or accumulation of deleterious mutations (see Grosberg and Cunningham 2000).

We need to understand the clonal structure of local *A. palmata* populations if we want to assess the status of this coral in the Caribbean. Several avenues have been pursued to detect clonal identity in Cnidaria. The first studies utilized self-recognition analyses (Neigel and Avise 1983) in *A. cervicornis*. This study found that *A. cervicornis* clones do not extend further than 20m. One clone may dominate areas of 10m^2 and

these clones are generally spatially discrete with tight boundaries. The genetic basis of tissue compatibility has since been challenged by studies showing fusion of electrophoretically distinct ramets. Analysis of protein (allozyme) and DNA markers show patterns from dominantly asexual to dominantly sexual reproduction in the Scleractinia. Even within the same species, contrasting reproductive behavior over large geographical scales is not exceptional (reviewed in Harrison and Wallace 1990). However, a lack of appropriate sampling design and the limited power of allozymes to resolve all genotypes limits the extend to which studies can be compared.

The consequences of asexual reproduction on genotypic diversity depend largely on the frequency of sexual recruitment and genet longevity. Empirical and theoretical studies have suggested that genotypic diversity at a local scale might decrease over time through elimination of genets by intraspecific competition or stochastic effects. In contrast, genotypic diversity might remain high if sexual recruits, however rare they might be, have a long life span after establishment occurred (McFadden 1997). In either case, interpopulation differences can be maintained (Hoffmann 1987).

Gene flow in the Caribbean

Opposing patterns of genetic population structure in the Caribbean have been predicted. High gene flow along major current paths (most recently Roberts 1997) may result in a gradient of genetic similarity, correlated within a current system, and would likely reduce subpopulation structure on small scales. Cowen et al. (2000) and others suggested that retention of larvae, aided by local current features, larval behavioral adaptations and high mortality rates should lead to highly subdivided populations. Studies of marine organisms demonstrate population patterns, from strongly structured to homogenous across the Caribbean basin. In the latter case, slight but significant microgeographic structure has been reported in the presence of high gene flow.

To date, there have been no studies on the population structure of Caribbean Scleractinia. However, geographic variation has been found in a number of Anthozoa in temperate and in tropical systems using allozyme and nuclear markers.

Burnett et al. (1995) predict that reef building corals show considerably more population structuring than has been described in strictly sexual species. The zoanthid *Zoanthus coppingeri is* only partly clonal but exhibits strong population structure between localities separated by only 50m, a consequence of random changes in gene frequencies as a result of low levels of gene flow. High clonal longevity and low sexual recruitment rates seem to maintain genetic differences over long periods.

If coral populations are largely self seeding and long-distance transport of larvae is a rare event, the Island Stepping Stone model predicts that genetic differentiation should increase with geographic distance with obvious management implications. Geographic and genetic distance were correlated in some cases.

Analysis of protein (allozyme) and DNA markers show patterns from dominantly asexual to dominantly sexual reproduction in the Scleractinia. Even within the same species, contrasting reproductive behavior over large geographical scales is not exceptional (reviewed in Harrison and Wallace 1990). However, a lack of appropriate sampling design and the limited power of allozymes to resolve all genotypes limits the extent to which studies can be compared.

Underlying the above discussion is the assumption that species with long lived planktonic larvae should have a higher dispersal potential than species with philotrophic, short lived, benthic or no larval stages. It cannot be ruled out that the failure to consistently relate reproductive strategies, with the amount of gene

flow in marine organisms, is due to the shortcomings of the markers and the statistical methods, rather than lack of pattern. Additionally, the fundamental differences between clonal and non-clonal species, both in terms of genetic structure and spawning strategies, further complicate predictions and call for different experimental approaches. It is essential to test the ability of the chosen marker system to reliably differentiate between clones (ramets, identical by descent) and closely related individuals (genets, identical by state) to reach confident conclusions about population structure. Furthermore, broadcast spawning corals like *A. palmata* only spawn annually and do so synchronously Caribbean wide. Thus, the potential for larval retention in local current features is likely to be different and, as of now unpredictable, across the Caribbean basin. Lastly, long generation times and low sexual recruitment will likely result in different time scales of larval exchange rates compared to sexual species.

Genetic structure of *A. palmata* is currently under investigation. Both clonal structure and reef connectivity will be estimated by combining highly variable, mendelian markers (microsatellites) with a nested sampling approach on a variety of spatial scales.

Summary

The presumed dominance of asexual reproduction in *A. palmata* leads to a number of predictions, namely small breeding population size and low genotypic diversity within populations. Genet longevity and low sexual recruitment are expected to produce population substructure in the Caribbean. This substructure might not conform to geographic distance or cluster along major current patterns. Rather, it is expected to be influenced by the volatile nature of local currents and eddies. Failure to detect subpopulation structure does not exclude the possibility of extremely rare exchanges of sexual recruits between populations due to the presumed long generation times in *A. palmata*. In the latter case, conclusions derived from genetic studies about the population status and Caribbean reef connectivity will be limited. Nevertheless, information on the clonal structure of the populations will aid in the decision making process on marine reserves and management plans.

References

Burnett WJ, Benzie JAH, Beardmore JA, Ryland JS (1995) Patterns of genetic subdivision in populations of a clonal cnidarian, *Zoanthus coppingeri*, from the Great Barrier Reef. Mar Biol 122: 665-673

Carvalho GR (1994) Genetics of aquatic clonal organisms. In (Beaumont AR, ed) Genetics and Evolution of Aquatic Organisms. pp. 291-323. Chapman and Hall, London

Crisp DJ (1978) Genetic consequences of different reproductive strategies in marine invertebrates. In (Battaglia B, Beardmore JA, eds) Marine organisms: Genetics, ecology and evolution. Plenum Press, New York

Grosberg R, Cunningham CW (2000) Genetic structure in the sea. From populations to communities. In (M. D. Bertness, S. D. Gaines,Hay ME, eds) Marine Community Ecology. pp. 61-84. Sinauer, Sunderland, MA

Harrison PL, Wallace CC (1990) Reproduction, dispersal and recruitment of scleractinian corals. In (Dubinsky Z, ed) Ecosystems of the world 25. pp. 133-207. Elsevier, Amsterdam, Oxford, New York, Tokyo

Hedgecock D (1994a) Does variance in reproductive success limit effective population sizes of marine organisms? In (Beaumont A, ed) Genetics and evolution of aquatic organisms. pp. 122-134. Chapman and Hall, London

Hedgecock D (1994b) Temporal and spatial genetic structure of marine animal populations in the California Current. Calcofi Rep 35: 73-81

Roberts CM (1997) Connectivity and management of Caribbean coral reefs. Science 278: 1454-1457

Scheltema RS (1986) Long-distance dispersal by planktonic larvae of shoal-water benthic invertebrates among central Pacific islands. Bull Mar Sci 39: 241-256

Coral Farm: the First Step to Restore Reefs

Antonio L. Ortiz-Prosper, Coordinator
Puerto Rico Coral Farmers, *Caborrojeños Pro Salud y Ambiente, Inc.*

Puerto Rico Coral Farmers is a marine scientific group within Caborrojeños Pro Salud y Ambiente, Inc. (CPSA), a non-profit organization registered in the Puerto Rico State Department since 1991. The mission of our organization is to raise awareness on issues regarding the conservation and protection of our environment. CPSA has the support of several local and federal agencies, including the US Department of Commerce, Rural Economic Development, Environmental and Natural Resources Department, among others. At present, we are currently working with the National Fish & Wildlife Foundation to develop effective and low cost methodology to restore coral reefs.

Our goal is to implement methods for manipulating and enhancing depleted coral population through coral farming in the Southwest area of Puerto Rico, specifically in Cabo Rojo, Lajas, and Guánica. We have designed specific procedures to collect, transport and culture of several coral species that will be continually tested on this study. Coral Farming is a proposed plan to overcome part of the problem of reef deterioration in Puerto Rico and the Caribbean. Through the culture of a wide diversity of corals, we will be able to supply corals to deteriorated coral reefs, damaged by natural (storms, and disease) and human induced disturbances (ship grounding, pollution, military activities, among others.)

Our Partners
·   Fish & Wildlife Foundation: Main partner that will provide the funding for the proposed project. Is the main sponsor of our current Reef Restoration Methodology Project (ending August 2001), where we developed the coral reef farming methodology, which will be implemented in a larger scale in the proposed project.
·   Department of Natural Resources and Environment (DNRE), Guánica State Forest: Will provide storage facilities for the equipment and materials, and to prepare the coral culture device needed for the coral nurseries.
·   Other partners: Local organizations such as the Ferré Rangel Foundation, and the Ford Motor Company Foundation have manifested their interest to collaborate in the proposed project, by providing additional funding to cover the costs of a vehicle to be used in the project (to transport heavy equipment, coral culture device, and trailer), and for an educational component, respectively.

Statement of the problem
In an effort to overcome the problem of coral reef deterioration, the active restoration of damaged coral reefs is now at the scope of most conservation efforts. Coral reef restoration is a relative new field of research that will become increasingly important for management purpose. Restoration techniques have the potential to accelerate the re-growth of a reef after disturbance and created new reef where none previously existed. The basic approach is to introduce new colonies of fast growing species into the reef. The establishment, growth, development and maturating of these colonies may increase larvae production and recruitment locally or the increase the number of colonies by the establishment of broken off fragments from transplanted colonies.

Despite the fact that some corals are known to survive after transplantation (Highsmith, 1982), some techniques have been proven not to be feasible options because of the following:

·   **Negative effects on collection sites**: The majority of the work done in coral reef restoration projects involve the collection of the coral colonies from one site, transported and transplanted to a second site. Harriot and Fisk (1988) have documented the negative impacts of transplantation on the collection site, such as the reduction of coral population from healthy reefs, among others.

·   **Highs cost, and low percent of survival of coral transplanted**: Cost/effectiveness is not measured in most of coral reef restoration project. For example, after the M/V Fortuna Reefer Vessel Grounding at Mona Island (Puerto Rico) the National Oceanic and Atmospheric Administration's Damage

Assessment and Restoration Program initiate an emergency coral reef restoration. After an expedited $1.25 million settlement funds to restore the reef less than 65 % of *Acropora palmata* fragments survived. Comparable results (68% after one year) were obtained without human intervention when hurricane Georges (September 22, 1998) passed through Puerto Rico, fragmenting many colonies of *A. palmata* in several reefs of La Parguera, southern Puerto Rico (Ortiz and Ruiz, 2000).

Farming corals (or coral nursery) is the best logical step in coral harvesting that will allow us to produce corals to be used on restoration projects. Our experience in coral farming has proved that coral nursery or coral culture is a useful tool in coral reef management. The coral nursery is based on the idea of the metapopulation concept. A metapopulation is a series of small, separate, populations united by some mechanism that allows genetic flow. In this scenario, even if the individual populations go extinct, other population survives and supply dispersing individuals who re-colonizes "extinct" patches (Harrison, 1991). By this concept, the coral culture of different species within the nursery sites may act as a source of corals to replenish extinct populations at different reefs. The proposed coral farm not only will increase the local genetic variability by the addition of new coral strains to the reef, it also will preserve coral strains (on coral nurseries) for future dispersion, including candidate species considered for the Endangered Species Act. For example, we have already successfully farmed *Acropora cervicornis* and *Acropora prolifera*, two of such threatened species.

Expected Results and Benefits
We will establish a total of 6 coral reef nurseries in three southwest towns: Cabo Rojo, Lajas and Guanica (2 nurseries in each town). Each of these nurseries will have at least 50 coral culture devices, for a total amount of 300. Initially, we will collect and culture in these device at least 8,400 coral fragments of different species. By the end of the second year, we expect to have harvested at least 30,000 fragments to be cultured in additional 1,440 new culture devices.

Outcomes
1. Implement effective methodologies for coral propagation and transplantation through human activities.
2. Increase of genetic diversity of local coral population by providing new, genetically different individuals .
3. To have farmed large and diverse amounts of corals, including threatened species of the *Acropora* genus, available to be used in future local reef restoration efforts.
4. Direct involvement of coral reef resource managers; island fishing communities and other non-government partners in coral reef restoration projects.
5. Integration of coral transplantation techniques in the management strategies for improving the fishery resources in Puerto Rico.
6. Increase public knowledge about the importance of coral reefs as essential habitats for marine life, and the joint efforts to preserve and restore damaged coral reefs.
7. Coral farms will also produce direct and indirect benefits to local areas by expanding habitats for marine invertebrates, ornamental and commercial fishes, and underwater attractions for snorkeling or SCUBA diving.

Our ultimate goal is to transfer our findings and experience in restoration and coral farming methodology to other Caribbean nations, as a sustainable method to increase coral populations
We propose the extensive use of experimental and proven methods of coral culture. All coral transplantation or cultured methods will be continually tested to determine the optimum approach. Each methodology will be tested and evaluated using appropriate experimental design. For example, experimental coral culture device will be set up in a complete randomized design. Triplicate coral culture device contained branches or fragments of one strain of each coral species will be randomly allocated within each coral nursery area. The number of coral fragments and its size within the experimental coral culture device will be recorded at the initiation of the project. Coral nursery sites will be visited periodically over the year period and the response variables to be measured are mortality rate of transplant, incremental growth, and colony conditions. All techniques (coral collection, transportation, transplantation, etc.) will be modified depending on previous results.

Coral Culture as a Conservation Tool for *Acropora* spp.

Erich Mueller, Ph.D., Director
Center for Tropical Research, Mote Marine Laboratory, Summerland Key, FL emueller@mote.org

During the past 20 years, aquarists have developed techniques to successfully maintain, and propagate, scleractinian corals in closed systems. Much of this was accomplished by hobbyists with the goal of creating "mini-reefs" for display. But the requirements for scleractinians were based on knowledge of coral biology, particularly their need for oligotrophic water and high irradiances. Scientists have also developed closed coral systems to better understand coral biology and their effects on community metabolism. The Acroporids are particularly amenable to culture because of their high growth rates and ease of asexual propagation. Coral model systems, such as the "microcolony," are the equivalent of lab rats and offer the potential to much more fully understand the complex physiological processes of corals and their symbiotic dinoflagellates. Closed-system culture offers opportunities to study diseases that affect acroporids (bleaching, white-band disease and patchy necrosis/white pox) in much more detail than possible in the field. Finally, such systems also offer a refuge of last resort for a genus that has seen dramatic population declines in much of the Greater Caribbean.

Management Measures for Corals and Coral Reef Ecosystems in the Florida Keys National Marine Sanctuary: Is the Existing Program Sufficient to Protect and Restore Acroporid Corals?

Brian D. Keller
Florida Keys National Marine Sanctuary

The Florida Keys National Marine Sanctuary is a nearly 10,000-km^2 marine protected area that was designated by Congress in 1990; its management plan was implemented in 1997 and consists of 12 action plans in four categories of protection: physical damage, environment/water quality, science/understanding, and penalties. A key aspect of the Sanctuary's management plan is the use of marine zoning to set aside areas for specific activities to balance commercial and recreational interests with the need for a sustainable ecosystem. In particular, there are 24 fully protected ("no-take") zones that help protect resources from overuse and separate conflicting uses. The Sanctuary's management plan includes multiple approaches to protecting live coral. Although *Acropora* spp. are not singled out within the plan, they receive special consideration in day-to-day operations. For example, there was a ban on collection of *Acropora* for research for several months following the damaging effects of Hurricane Georges in 1998.

Introduction to the U.S. Endangered Species Act

Andrew W. Bruckner
NOAA/NMFS, Office of Protected Resources, Silver Spring, MD.
Andy.Bruckner@noaa.gov

BACKGROUND

The purposes of the Endangered Species Act are to provides a means to conserve ecosystems upon which endangered species and threatened species depend, to provide a program for the conservation of endangered and threatened species, and to take appropriate steps to recover a species.

Species' Listings Under the Endangered Species Act

The National Marine Fisheries Service (NMFS) is responsible for determining whether marine species, subspecies, or distinct population segments are threatened or endangered under the Endangered Species Act of 1973, as amended, 16 U.S.C. 1531 et seq. (ESA). To be considered for listing under the ESA, a group of organisms must constitute a "species," which is defined under section 3 of the ESA to include "any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." NMFS has determined that, to qualify as a distinct population segment (DPS), a population (or group of populations) must be substantially reproductively isolated and represent an important component in the evolutionary legacy of the biological species. A population (or group of populations) meeting these criteria is considered to be an "evolutionarily significant unit" (ESU) (56 FR 58612, November 20, 1991). In its listing determinations to date, NMFS has treated an ESU as the equivalent of a DPS under the ESA.

Section 3 of the ESA defines an endangered species as "any species which is in danger of extinction throughout all or a significant portion of its range" and a threatened species as one "which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." The statute lists factors that may cause a species to be threatened or endangered (ESA section 4(a)(1)), but it does not provide further guidance on how NMFS is to determine the risk of extinction or the likelihood of endangerment.

Section 4(b)(1)(A) of the ESA requires NMFS to make listing determinations based solely on the best scientific and commercial data available after conducting a review of the status of the species and after taking into account efforts being made to protect the species. Accordingly, in making its listing determinations, NMFS first determines whether a population group constitutes a "species" under the ESA, and determines the species' status and the factors that have led to its decline. The status review provides background information on the species including taxonomy and biology, current and historic range, population information, habitat requirements, a summary of the threats faced by the species, a review of existing conservation measures, and a discussion of the activities that would be affected if the species were listed.

The process for determining whether a species should be listed is based solely on scientific information on the status of a species and specifically excludes potential economic impacts. The status is determined from an assessment of factors that may be contributing to decline including 1) habitat destruction or modification; 2) overexploitation; 3) disease or predation; 4) inadequacy of existing regulatory

mechanisms; and 5) other factors affecting survival of the species. NMFS also assesses protective efforts being made to determine if they mitigate risks to the species.

Invertebrate listings

An amendment to the ESA in 1978 allows us only to list distinct populations of vertebrates. Marine invertebrates must be threatened or endangered throughout their range to be listed, because they are thought to have greater ranges and fecundity and a greater resilience to exploitation and environmental change than vertebrate species. Since most benthic inverts produce pelagic larvae with the potential for long-distance dispersal, these species are assumed to exhibit a high degree of interconnectivity through water circulation, and it is thought that a distant population in good condition can serve as a source of recruits to rehabilitate degraded populations.

Even though we are required to list all populations of an invertebrate species if we determine that they are threatened or endangered, the degree or type of protection these species receive can vary, depending on whether a species is listed as threatened or endangered. If we were only to list one or both of these corals as threatened we would subsequently issue regulations through a rule-making process that would specify what measures were necessary for the conservation of the species and where these measures would apply. In some cases these rules would only affect the species in state or territorial waters if the state has a cooperative endangered species agreement and the state feels that those measures are beneficial for the species. In contrast, if we were to list one or both of the corals as endangered all of the provisions of the ESA automatically apply, regardless of whether the species is in federal waters, or in state and territorial waters. So a threatened listing gives us much greater flexibility.

What does it mean to be listed
A. Critical Habitat

When we publish a final decision to list a species on the ESA we are required to designate critical habitat - Critical habitat includes specific areas that contain the physical, biological and environmental factors necessary to support the species, as well as areas that are not occupied by the species, but are essential for its conservation - for corals, this could include other reef environments, as well as mangroves and grassbeds.

B. Protective measures

By listing a species, we are required to protect that species and recover it to its former abundance or range, concentrating on areas that are critical to the species based on unique genetic diversity, areas with a documented high abundance, populations that may provide a significant source of recruits to other areas, and populations at the geographic limits of the species. The ESA also provides us with the tools to protect the habitat occupied by a listed species by prohibiting any activities that are funded, authorized, or carried out by the federal government if those activities are likely to contribute to the degradation of the habitat and jeopordize the survival of the species (section 7). For coral reefs, this measure would require permits for any activities involving dredging, coastal development projects, sand extraction and discharge of sediment near coral reef environments. The ESA (section 9) also makes it illegal to "harass, harm, pursue, shoot, wound, kill, trap, capture, or collect or engage in commerce in listed animals except by permit for conservation or scientific purposes". Harm has been defined to include "significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns including breeding, feeding, or sheltering". A listing also increases federal aid to state and commonwealth

conservation agencies with cooperative endangered species agreements. Most importantly, The ESA requires that we develop and implement a recovery program.

C. Recovery Programs

A recovery program includes a summary of information on a species and its life history, including information on taxonomy, population discreteness, population size and trends (including past and present size and future projections based on current trends), reproduction and recruitment rates, sources and rates of mortality, diet and feeding habits, movement patterns, habitat use patterns and critical habitat requirements. The threats affecting the species should be described in detail, as well as the overall objective of the recovery plan, the type of recovery actions, and an implementation schedule to achieve these actions. The goals of the recovery program are to determine actions necessary to reduce or eliminate the threats affecting the species and protect critical habitat essential for the survival of that species. The recovery program must also identify measurable criteria that will be used to down-list a species once it has recovered, and an analysis of the time and cost required for full recovery.